MONOGRAPH—20

THE RELATIONSHIP BETWEEN HABITUATION TO VESTIBULAR STIMULATION AND VIGILANCE: INDIVIDUAL DIFFERENCES AND SUBSIDIARY PROBLEMS

Robert S. Kennedy

July 1972

NAVAL AEROSPACE MEDICAL RESEARCH LABORAT

PENSACOLA, FLORIDA

213

Approved for public release; distribution unlimited.

THE RELATIONSHIP BETWEEN HABITUATION TO VESTIBULAR STIMULATION AND VIGILANCE: INDIVIDUAL DIFFERENCES AND SUBSIDIARY PROBLEMS

Robert S. Kennedy

<u>Approved by</u>

Ashton Graybiel, M. D.
Assistant for Scientific Programs

<u>Released by</u>

Captain N. W. Allebach, MC, USN
Officer in Charge

3 July 1972

Naval Aerospace Medical Research Laboratory
Naval Aerospace Medical Institute
Naval Aerospace Medical Center
Pensacola, Florida 32512

THE RELATIONSHIP BETWEEN HABITUATION TO VESTIBULAR STIMULATION AND VIGILANCE: INDIVIDUAL DIFFERENCES AND SUBSIDIARY PROBLEMS

By

Robert Samuel Kennedy

Submitted in Partial Fulfillment

of the

Requirements for the Degree

DOCTOR OF PHILOSOPHY

Supervised by Dr. G. R. Wendt

Department of Psychology

The University of Rochester

Rochester, New York

1972

ib

Vitae

Robert Samuel Kennedy was born in Bronxville, New York, on 10 January 1936. He attended Evander Childs High School, Bronx, New York, and was graduated in June, 1953. He then attended Iona College, New Rochelle, New York, where he majored in English and minored in Philosophy and Psychology. Upon graduation from Iona College in 1957 with a B.A. degree, he enrolled that summer in an eight-credit undergraduate psychology course at Fordham University, and began graduate study there in the fall of 1957. In January, 1959, he received the Master of Arts Degree in Experimental Psychology. The subject matter of his dissertation was visual adaptation and was supervised by Professor R. T. Zegers. While still at Fordham University during the 1958-59 academic year, he completed a clinical clerkship, for which the practicum was conducted at St. Vincent's Hospital, New York, New York.

In September, 1959, Mr. Kennedy accepted a commission as an Ensign in the United States Navy Medical Service Corps and was assigned to the Psychology Department of the Naval Aerospace Medical Institute in Pensacola, Florida. While there, his interests in sensory psychology broadened to include vestibular functions, and he conducted laboratory and field studies of motion sickness, disorientation and vertigo, and taught courses in aviation psychology. He became a career Naval Officer and while still on active duty was selected for sponsorship of graduate study by the U. S. Navy Bureau of Medicine and Surgery. In June, 1965, he began attendance in the Psychology Department at the University of Rochester.

His graduate studies at the University of Rochester emphasized vestibular functions, sensation and perception, and human engineering. During his stay at the University of Rochester, Professor G. R. Wendt was his advisor and main teacher.

In 1967, he completed his coursework at the University of Rochester, and returned to the Naval Aerospace Medical Institute, Pensacola, Florida, where he began work on his dissertation out of residence. He was promoted to Lieutenant Commander in 1968. During his tour in Pensacola he was Division Officer in the Aerospace Psychology Division, and in addition to his dissertation research, conducted studies in aviation psychology. He was awarded the Navy Commendation Medal in 1970 for active participation in and studies of motion sickness in various force environments.

Mr. Kennedy is an Associate Fellow of the Aerospace Medical Association, a member of Human Factors Society, New York Academy of Sciences, U. S. Naval Institute, Undersea Technology Society, American Association for Advancement of Science, and an Associate Member of the American Psychological Association and Division 19.

He is the author of about sixty publications and presentations and is listed in American Men of Science, 1970, and Leaders in American Science, 1965.

In 1970, a medical emergency in his family occasioned his transfer from Pensacola to the Naval Medical Research Institute, Bethesda, Maryland, where he is presently working.

LCDR Kennedy is married with four children.

Acknowledgments

The author gratefully acknowledges the assistance of the following:

Professor G. Richard Wendt for his non-directive influence on my entire graduate career and for the philosophy, attitudes, strategies and ideas he has imparted to me about psychological research. In particular, I thank him for being responsible for extracting from me the main idea for this thesis.

Dr. Fred E. Guedry, who advised me on the conduct of my thesis after I left Rochester, and was always available for encouragement or skepticism, as needed. In particular, I thank him for his suggestions following a careful reading of a first draft of this manuscript.

Dr. Ashton Graybiel for introducing me to vestibular functions, and for providing the research setting where this dissertation was accomplished.

The late Mr. J. R. Berkshire, my supervisor during the data collection stage of this dissertation, for the freedom he permitted in my work schedule, as well as for other debts I incurred over ten years of professional association and friendship.

Miss Edna Marques and her staff in the Student Prediction Section for their assistance in scoring and tabulating the data, and Mr. Richard Irons, Mrs. M. Duty, and their staff in the Data Processing Department for their support.

Dr. J. I. Niven for the use of the Human Disorientation Device, and his assistant, Mr. A. Thomas, who operated and maintained the apparatus.

Dr. A. J. Bachrach, who encouraged me to complete writing this

dissertation and provided the time and space to do it.

U. S. Navy, Bureau of Medicine and Surgery for funding my two academic years at the University of Rochester, and who also provided general support for the dissertation research.

The approximately 5000 student Naval aviation personnel who gave of their time in order to be included in this study as subjects, and in some cases assisted in scoring nystagmus records.

My family for their confidence, understanding, tolerance and love, but especially to my wife, who successfully filled many roles, the last role having the most practical significance: My typist - to whom this thesis is dedicated.

Abstract and Summary

A number of investigators have pointed out that the mental state of the subject is an important variable in studies of habituation to vestibular stimulation.

The present study is in three parts. In the first part the relationship between vigilance performance and nystagmus habituation was studied, and in the second part the relationships of personality scores to vigilance and habituation were investigated. A third part was concerned with clarifying relations between personality measures, and vigilance performance in tasks of different complexities.

In the first part of this investigation (Experiment I, Part 1), sinusoidal oscillation through short arcs (75 degrees, 12 cycles per minute) served as the vestibular stimulus for 100 student pilots. Half the subjects received no experimental control of mental state, and half performed an auditory vigilance task. The performance task controlled and permitted continuous assessment of vigilance for each subject for the 50 minutes of his oscillation. A third group of 50 subjects performed the vigilance test in the absence of vestibular stimulation.

Nystagmus was scored on a 10 point scale for each oscillation cycle (five seconds) for each subject. In this scoring procedure, a series of compensatory slow phases followed by fast phases in the opposite direction were considered to be good nystagmus responses. Eye movements which bore no systematic relationship to the stimulus or which had no fast phases were

scored as vestibular habituation. The reliability of the habituation scoring procedure was excellent (generally $> .95$). More habituation occurred in the group whose mental state was uncontrolled. No differences in vigilance scores were found between the two groups who were or were not oscillated.

The average correlation between nystagmus and vigilance within a subject was very low, but significant ($r = .27$; $P < .001$). These findings are relevant to studies of relations between habituation and vigilance. The application of eye movements as a potential independent measure of alertness in moving environments and elsewhere is discussed.

In Experiment I, Part 1, two other findings are reported:

1. Voluntary eye movements after exposure to long term oscillation (> 30 minutes) bore essentially no relationship to the frequency of the oscillation stimulus the subjects experienced nor to the magnitude of the habituation or vigilance decrement shown by a subject.

2. The point at which the eyes change direction (Zero slow phase eye velocity) within an oscillation cycle appeared to change, being initially in phase with velocity, as is customary for this stimulus profile, but becoming progressively earlier (i.e., leading the stimulus) over time and as arousal decreased.

In the second part of Experiment I, an effort was made to relate certain subject variables (e.g., personality scores, hours sleep) to vestibular habituation and to vigilance performance. Other investigators with different vigilance tasks had obtained positive findings with the extravert phenotype, and measures of extraversion as well as field independence were included in this

study. In addition, a self report questionnaire which inquired about general fitness was studied. Correlations between personality and history, on the one hand, and vigilance performance or nystagmus habituation, on the other, were small and for the most part insignificant. However, correlations between "ability" on the vigilance task and the vigilance "decrement" suggested that certain individual differences and vigilance performance interact with task complexity in important ways.

In the third part of this study (Experiment II), 200 subjects were tested; half on a simpler and half on a more complicated vigilance task than was used in the previous section. Separate scores of a subject s ability to do the work and vigilance on the work were calculated. Performances were related to the same subject variables (history and personality test scores) as previously.

The results showed that "extravert" and "ability" scores were related to vigilance scores in different ways as a function of task complexity. Vigilance of extraverts was relatively poorer on the simple (one-channel) test, but relatively better on the complex test ($P < .01$). Also, a subject's score at that point in the three-channel vigilance session when the group performed best was correlated with his decrement ($P < .05$). An equivalent relationship was not found in the one channel test. The fact that opposing predictions can be made about individuals as a function of task complexity can have important practical implications. It was hypothesized that a trait exists differentially in a population that is essentially homogeneous in what is usually meant by intelligence. It is felt that this trait permits certain persons to be able to monitor

many channels of information at once. Further, it is offered that possession of this trait is negatively correlated with an ability to monitor one channel of information for a long time. The data are discussed from the standpoint that persons with the capacity for high scores on a three-channel test tend not to be vigilant persons. The suggestion is made that persons who are "multi-channel" can be contrasted with persons who are "long term samplers".

Subsidiary findings are reported in appendices to the main body of this report. These latter studies are largely methodological and deal with difficulties in electro-oculographic recording, norms, reliabilities and validities of personality tests, reliability of nystagmus scoring and attributes of the vigilance task.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Vestibular functions						
Vigilance						
Individual differences						
Personality						
Electro oculography						
Habituation						
Nystagmus						
Performance						
Aviation selection						
Extraversion						
Field independence						
Normative performance test data						
Eye movements						
Personality correlates						
Complex monitoring						

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Naval Aerospace Medical Research Laboratory Pensacola, Florida 32512	2a. REPORT SECURITY CLASSIFICATION Unclassified	
	2b. GROUP N/A	
3. REPORT TITLE THE RELATIONSHIP BETWEEN HABITUATION TO VESTIBULAR STIMULATION AND VIGILANCE: INDIVIDUAL DIFFERENCES AND SUBSIDIARY PROBLEMS		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) N/A		
5. AUTHOR(S) (First name, middle initial, last name) Robert S. Kennedy, LCDR MSC USN		
6. REPORT DATE 3 July 1972	7a. TOTAL NO. OF PAGES 190	7b. NO. OF REFS 13
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) MONOGRAPH 20	
b. PROJECT NO.		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.		
11. SUPPLEMENTARY NOTES N/A	12. SPONSORING MILITARY ACTIVITY N/A	

13. ABSTRACT

It has been shown that a subject's mental state is an important variable when recording vestibular nystagmus. This experiment is in three parts. In the first part the relationship of one form of mental work (vigilance scored in percent correct) to vestibular nystagmus habituation and eye movement phase relationships recorded during prolonged cyclic oscillation was studied. In the second part individual differences (personality, hours sleep, etc.) were related to vigilance performance and nystagmus habituation. In the third part the interaction of subject variables with vigilance tasks of differing complexity is reported. In addition, methodological studies are appended to the main body of this monograph. These include: 1) a bibliography and experiments concerning effects of luminance on electro oculographic potentials; 2) normative data for a vigilance task; 3) correlations between personality (extraversion, field independence) and success in aviation training and 4) reliability and validity of a scoring method for nystagmus habituation.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

Unclassified

Security Classification

Table of Contents

List of Tables

List of Figures

General Statement

Strategy

The general form of experiments in the behavioral sciences follows the stimulus-response paradigm, whereby careful control is exerted over the stimulus and the output of the organism is measured to ascertain orderly relationships. Concern with the temporal and intensitive aspects of the stimulus-response relationships gives rise, for example, to studies of learning and psychophysical scaling, respectively. The present study is concerned with changes in responses which occur during a prolonged period of cyclic vestibular stimulation.

Variabilities between and within organisms in reactivity make statistics an important methodology in psychological data analyses. Many studies of individual differences consider these differences to be error or error variance. The present plan is to study individual differences as potential correlatos of other variables.

Exposition

Evidence in the research literature suggested that behavioral indicants of arousal (e.g., percent correct on a vigilance task) might covary with aspects of habituation to vestibular stimulation (eye movement changes).

Furthermore, some independent variables, such as hours sleep and personality scores might predict vigilance or habituation differentially.

Separate programs were undertaken simultaneously to gain wider experience with a vigilance task, nystagmus habituation, personality tests, and other

paper and pencil tests, as well as to study the methodological and procedural variables attendant thereto. All the subjects were drawn from a Navy flight student population which had been selected according to a number of set criteria already established by the Navy. Therefore, it was a fairly homogeneous population. With the exception of the paper and pencil tests, each subject was tested only once.

The reports of the experiments which follow are presented in the order they were conceived, rather than the order in which they were conducted.

Experiment I, Part 1

Relationship of Vigilance to Nystagmus Habituation

Vestibular eye movements. Vestibular nystagmus is a term usually used for the involuntary eye movements which occur in connection with stimulation of the semi-circular canals (Wendt, 1936b). The form of the eye movement includes a slow deviation, which is believed to have its genesis in the canicular end organ (specifically, the hair cells of the cupula), and which serves to maintain the position of the eyes in space when the head moves relative to earth (Camis, 1930; Guedry, 1965; McCabe, 1965; Wendt, 1936b, 1950). The second movement, the fast phase, is presumably of more central origin (Gernandt, 1959; McCabe, 1965; Wolfe, 1966) and serves to return the eyes to the normal line of regard. Essentially, the same anatomical pathways are described by many authors (Brodal, 1966; Brodal, Pompeiano & Walberg, 1962; Cohen, Suzuki, Shanzer & Bender, 1964; Gernandt, 1959; Wolfe, 1966). According to Gernandt (1959), the best neurophysiological evidence indicates that the generator potential for the slow phase is in the hair cells of the ampullae of the semicircular canals, and the pathway to the eye muscles most probably includes: Nerve VIII; the nuclei of Nerve VIII; the medial longitudinal fasciculus; the nuclei of the oculomotor complex (Nerves III, IV, and VI); and the eye muscles. In addition, collaterals go to, among other places, the cerebellum and reticular formation. Since the fast phase is absent in humans with lesions of the pontine reticular formation (Daroff & Hoyt, 1971), this site is probably implicated in the fast phase responses. Evidence that the slow phase response remains

essentially unchanged for long periods of stimulation suggests the analogy of the slow phase response to a mechanical servo system (Gonshor & Jones, 1969; Wolfe, 1966).

Vestibular eye movements and a sinusoidal stimulus. A very clear account of the various types of stimulus (angular acceleration) response (nystagmus) relationships is given by Guedry (1965, pp. 66-84) and Wendt (1936b, 1951). The difference between responding to angular acceleration in one direction (Guedry, 1965) and to oscillation (Travis & Dodge, 1928) is discussed by Wendt (1936b). Also, the similarity of sine wave oscillation (within certain frequency and amplitude ranges) to the customary movements of the head has been commented upon by Camis (1930, p. 75), Guedry (1965), and Travis & Dodge (1928). Prolonged cyclic oscillation was selected for the present study since it was felt that a "natural" or physiological stimulus would be more conducive to habituation, and it was believed that findings from this type of stimulation would be more likely to be generalizable to other conditions than results obtained from stimulations which were unusual and not frequently encountered except in the laboratory.

Phase relationships of vestibular eye movements to a sinusoidal stimulus. Niven, Hixson & Correia (1965) have studied several parameters of vestibular eye movements as a function of various stimulus variables. Their series of studies utilize sinusoidal oscillations as stimuli and report the responses of the eyes over a range of displacements, velocities and frequencies. They conclude, as do others (e.g., Robinson, 1969; Young, 1968), that the mechanical characteristics of the end organ (viz., the cupula) are such that the velocity

of the eye movements which result from sinusoidal oscillation are in phase with the velocity of the stimulus throughout the middle range of frequencies (12-24 cycles/minute) tested, and their results support and extend the earlier findings of Wendt (1936b) (See also Appendix E). In addition, Niven et al. (1965) describe the phase angle of the eyes relative to the stimulus and name it a "phase shift". They measure the angle between (a) the point at which the eyes reach zero velocity relative to (b) the zero acceleration of the stimulus. This "phase shift" is approximately 90 degrees for frequencies between 12 - 14 cycles/minute for the displacements they tested. Steele (1965, p. 56) has suggested that comparing the difference between "the velocity of the stimulus" and "the velocity of the eyes" would result in a simpler presentation, but Niven et al. (1965) point out that acceleration is the appropriate stimulus and at lower frequencies (i.e., < 6 cycles/minute) adopting Steele's suggestion, would produce a "phase advance". There are merits to both positions; however, the terminology of Niven et al. (1965) will be used here because it will facilitate comparisons with their results elsewhere in the present studies.

One purpose of part of the present investigation was to observe what changes, if any, occurred to the "phase shift" after long term oscillation. It was hypothesized that the phase shift would be invariant over time for a given set of sinusoidal oscillation parameters.

<u>Theoretical implications of post effects from long term cyclic oscillation.</u> Since at least the time of Helmholtz (1925), students of eye movement have been bothered about whether a position sense for the eye exists. Helmholtz felt one

did not exist, but Crawford (1960a, 1960b, 1960c, 1960d), in an elegant series of studies in man, has shown that in the dark it is possible to position the eyes volitionally within $\pm$ two degrees of retinal angle. Further, Manni's group (Azzena, Desole & Palmieri, 1970; Manni, Azzena, Casey & Dow, 1965; Manni, Bortolami & Desole, 1968) has shown that evoked responses due to stretch receptor stimulation have been recorded in the mesencephalon in the area of the nuclei of Nerve V and in the cerebellum. With the exception of these findings, it is generally agreed (see for example Bach y Rita & Collins, 1971) that if a position sense exists, it is gross, not particularly useful and, in general, not available to consciousness. Furthermore, when vestibular stimulation is employed to elicit nystagmus in the dark, one's eye movements are not perceived. Retrospective reports by subjects in vestibular studies suggest that only extreme deviations of the eyes are felt (i.e., perceived), and the latter are most probably felt through the lids and not the eye muscles themselves. On the other hand, while it seems as though these involuntary eye movements are not perceived, studies of the oculogyral illusion (Graybiel & Hupp, 1946), point out the problem is not a simple one. It has been shown that following reports of the oculogyral illusion with an external target, the eyes themselves don't move (Byford, 1963; Yessenow, 1969, especially pp. 56 - 60). Yet, the neural coding of this illusion is such that an almost perfect correspondence exists between the perception of the magnitude of the illusion (in degrees per second) and what the vestibular eye movement would have been

(in degrees per second) at that point in time, if the target had not been presented (Yessenow, 1969). However, when afterimages are used, the eyes do move and the velocity of the eyes and the oculogyral illusion again are highly correlated (Yessenow, 1969). The above suggests that the coding of the afferent signals to the oculomotor nuclei (III, IV and VI) from the vestibular nuclei (VIII) is carefully preserved and relayed to an eye movement control center somewhere in the central nervous system.

Whether afferent signals to the eye muscles could produce a "neural trace", and whether these messages could be recorded later in the form of voluntary responses following an extended period of vestibular stimulation, would be of some interest. The design of the present study permitted this analysis. It was anticipated that the frequency of the sinusoidal oscillation would effect a change in voluntary sweeping eye movements (recorded in the dark after a long period of oscillation), and the obtained eye movements would bear a relation either to aspects of the stimulus or amount of habituation evidenced in a subject during oscillation.

Habituation. It has been known for some time that when vestibular stimulation is repeated, the response to the stimulus decrements (i.e., habituates). Good reviews of the earlier vestibular studies appear in McNally & Stuart (1942), a general review of habituation appears in Harris (1942), and a general theory in Wendt (1936a). Wendt (1950, 1951) pointed out that care should be taken in the control of the subject's mental state, since, if he be allowed to daydream, habituation appears more readily than if he is cautioned

to attend to the stimulus. Psychologists (then at the Fort Knox Laboratories) picked up this suggestion and have clearly shown that certain kinds of nystagmus can be retrieved in otherwise habituated subjects if a stimulus is presented which alerts the subject[1]. The finding that the fast phase of nystagmus is absent in persons with lesions in the pontine recticular formation (Daroff & Hoyt, 1971) and the similar result reported by Barany sometime ago (1907, cited by McCabe, 1965) suggests that the fast phase should be examined for the relationships to arousal.

There is a great deal of inconsistency in the research literature concerning the meaning of the term "habituation", and confusion has resulted. Reasons for the confusion may be due to the fact that the same word is used to describe an effect (e.g., the dropping out of a response) brought about by different processes; but often a process is implied[2].

In the present study, characteristics of the fast phase will be examined and their disappearance will be operationally defined as habituation. Because nystagmus which is "habituated" can be retrieved by alerting the subject (Guedry, 1965; Wendt, 1950, 1951), and because of the relationships described by Daroff & Hoyt (1971), it was hypothesized that some characteristics of the fast phase of nystagmus would be related to measures of mental work. The

[1]Guedry (1965) was able to reference 20 papers by this group (Guedry, Collins & Crampton) for the period of 1961-1964.

[2]The logical converse that the same process can have different effects (i.e., outputs) can increase the confusion. Analogous difficulties exist in descriptions of stress reactions and vigilance decrements where processes are also implied from effects.

study of the relationships of nystagmus habituation to other measures of mental work will be the main purpose of this experiment.

Apparatus and Procedure

Subjects. One hundred fifty student Naval Aviation personnel comprised the experimental population. All subjects had passed stringent physical and psychological examinations on which they would compare favorably with average college students. All were recent college graduates and the sample was homogenous (mean age in years = 23.1; SD 1.1; range 20 - 26). The experimental subjects were drawn each week from a larger class (N ≅ 50) of indoctrinees to Naval Aviation training. The subjects were assigned to one of three experimental groups (I, II, and III). All selections were made on the basis of the initial letters of the students' last names. Different letters were used for each group, and each week the letters were systematically changed. The subjects were informed of the purpose of this technique and instructed that they should not attach any special importance to being selected; in other words, no deception was employed. Mean differences on several cognitive variables between experimental groups and the entire population were small and insignificant, except those described more fully in Appendix A. All subjects appeared to be well motivated.

The three groups received different experimental treatments: Group I was oscillated for 50 minutes while alertness was measured and partly controlled by a complex auditory vigilance test; Group II was oscillated for 30 minutes, and the only controls for mental state were cautions to the subjects against sleeping and/or closing their eyes; Group III received the vigilance test only.

Apparatus. The major piece of experimental equipment was the Human Disorientation Device (HDD), which is described in detail elsewhere (Hixson & Niven, 1963), and appears in Figures 1, 2 and 3. The HDD is capable of rotation and oscillation about two axes, but in the present study, subjects were seated upright and oscillation about the vertical (spinal or Z) axis was utilized only. Control over sinusoidal oscillation is sufficiently precise for the purpose of this study. A wide range of stimulus parameters is available with this device. The subject's compartment of the HDD is a large, light-tight cab within which a subject may be positioned so that his head is at the axis of rotation. Response switches (including a "panic button") are placed at each arm rest. A restraint harness and open microphones are additional safety features.

Electro-oculography. Eye movements were recorded by standard electro-oculographic methods (cf. e.g., Ford & Leonard, 1958; Marg, 1951) using silver electrodes mounted at the outer canthi of both eyes and an indifferent lead on the forehead. AC recordings of eye movements were made on a Beckman EEG recorder. A 2.5-second time constant was used; this was considered adequate for the purposes of the present study (Tursky & O'Connell, 1965).

Subjects were dark-adapted for 20 minutes to minimize changes due to the effects of luminance on the corneoretinal potential. The results of three studies of these effects appear in Appendix B, along with a bibliography of electro-oculographic recordings. Calibrations were accomplished at specified periods within the experiment by having a subject gaze back and forth between

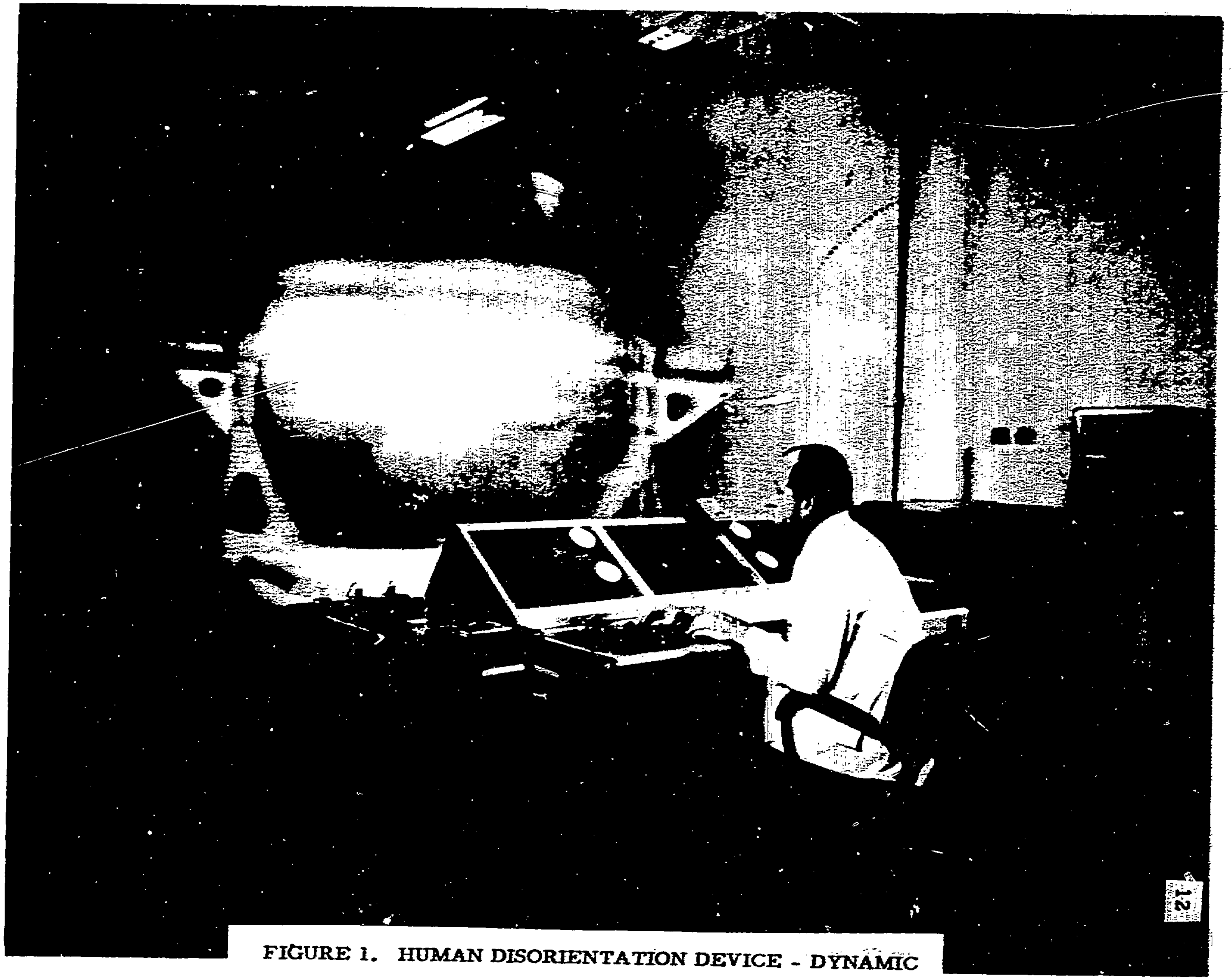


FIGURE 1. HUMAN DISORIENTATION DEVICE - DYNAMIC

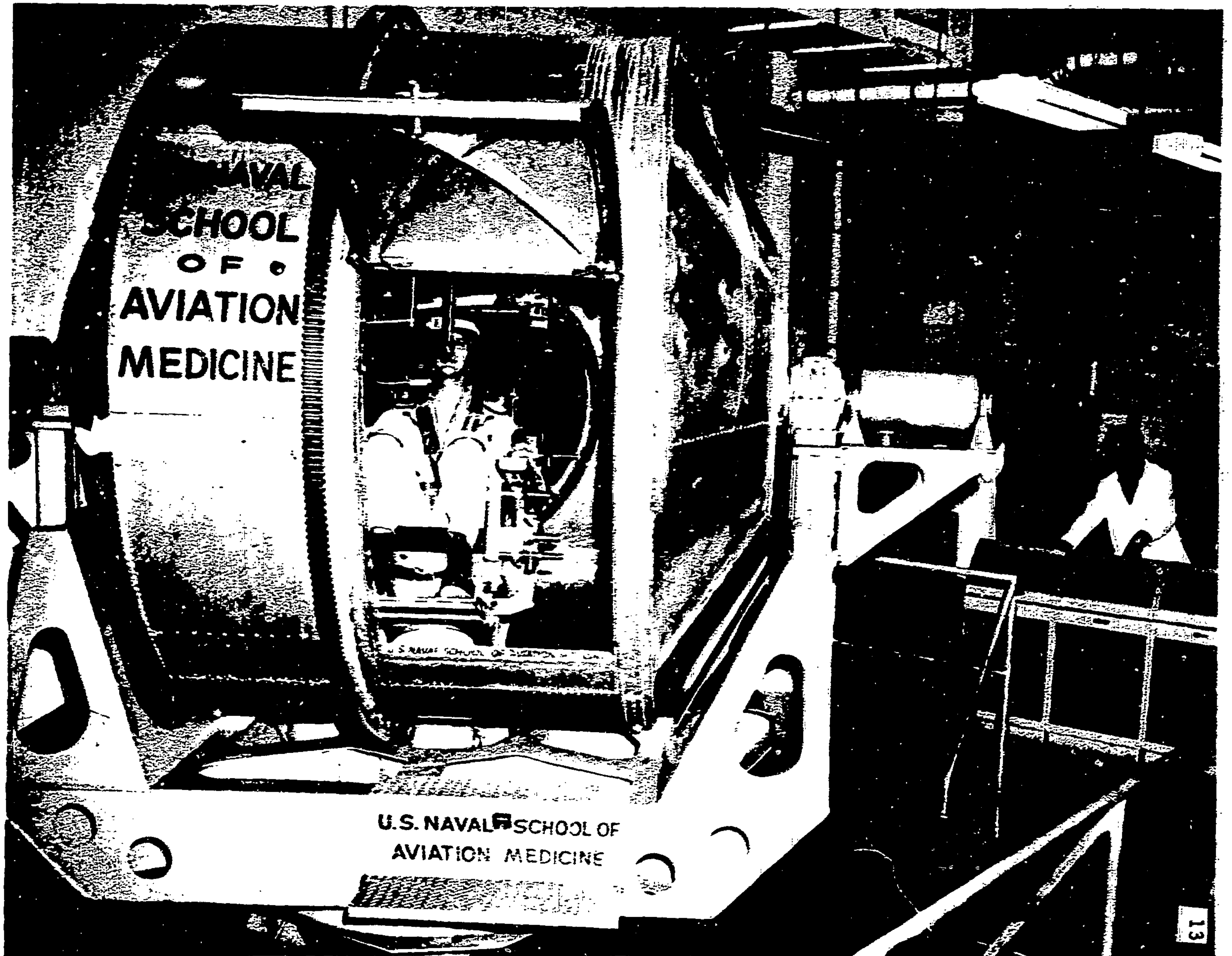


FIGURE 2. HUMAN DISORIENTATION DEVICE - STATIC

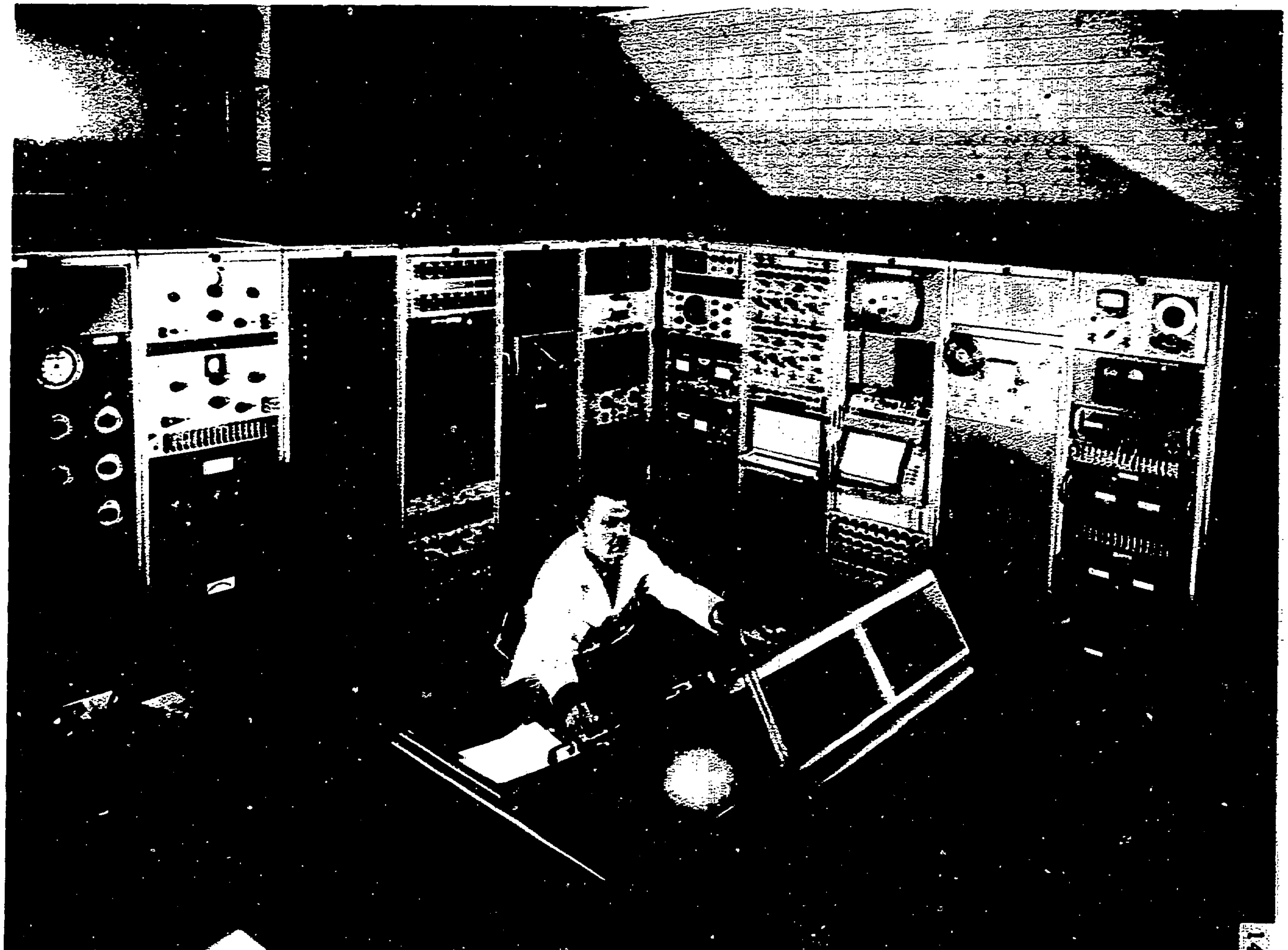


FIGURE 3. CONTROL CONSOLE AND RELATED EQUIPMENT FOR THE HUMAN DISORIENTATION DEVICE

two pinpoint lights of low luminance, each of which were 20 degrees of retinal angle from the normal line of regard. Efforts were made to adjust recording amplification so that about one degree of eye movement could be resolved on the recording paper.

Oscillation. The rationale for using oscillation as a stimulus to the vestibular system was described earlier, and a pilot study was conducted to explore the effects of different oscillation stimulus values.

Thirty subjects were exposed to various combinations of the following stimuli: (a) Frequencies (5 - 25 cycles per minute [cpm]); (b) angular displacements (15 - 270 degrees); (c) oscillation session length (15 - 60 minutes).

In addition, because long sessions (e.g., 60 minutes) would result in very lengthy records (about 100 yards) at the recording paper speed frequently employed in vestibular studies (viz., 25 mm/sec.), various recording paper speeds were observed, also[3].

Because mental work might influence the time course of habituation, some subjects were oscillated while monitoring auditory signals in the dark and others were oscillated in the dark, in quiet, after instructions of not to "sleep, or even close the eyes more than necessary."

Stimulus factors (frequency, displacement, session length), subject states (with and without mental work), and paper speeds appeared to interact, and it

[3]The reliability of sampling portions of a subject's record, reported in Appendix E, was generally high, but was not known at this time. Because the reliability of scoring full records was also not known, sampling did not appear to be a reasonable alternative.

was felt that a 12 cpm frequency with 75 degree displacement (47 degree/second peak velocity) at 10 mm/sec. paper speed for 50 minutes (with mental work) and 30 minutes (without mental work) was the best combination for the present study.

Two groups of 50 subjects were oscillated in the dark under the above conditions for 30 and 50 minutes respectively. The former is not strictly a control group, since their dark adaptation period (cf. Appendix B) was shorter and they did not practice the vigilance task. However, the main purpose of using the group was to determine whether the absence of controlled mental occupation (viz., the vigilance task) facilitated nystagmus habituation. This group's shorter overall experimental time by itself should, if anything, result in less loss of arousal, and thus provide a more stringent test of the alerting properties of the vigilance task.

Eye movement scoring. Nystagmus was scored by a modification of the method of Wendt (1967). The simplest description of the method employed here is that the "goodness" of the fast phases[4] occurring within each cycle (five seconds) of sinusoidal oscillation was assigned one of ten scores from 10 - 100. In addition, lower scores of five or one were used when "doubtful" or absolutely no" nystagmus was present, respectively. Samples of each scoring category are shown in Appendix E, as well as a general discussion of nystagmus. The reliabilities and validities of the method were generally high (r = >.95) and are

[4] Wendt (1965) feels that other eye movement responses should also be scored. In particular, abundant, frequent fast phases with large displacements occur in habituated records when smaller arcs of oscillation (30°) were used.

reported in detail in Appendix E. Numbers from 1 - 100 were used in order to deal with whole numbers and to be able to plot nystagmus and vigilance on similar ordinates. Each subject's record was scored in its entirety. Thus, for the 50-minute sessions, 600 determinations were made for each subject; and 360 for the 30-minute session. Average scores for each five-minute segment were obtained in order to compare vigilance and nystagmus scores.

Particular care was taken not to be influenced by amplitude in scoring the nystagmus records of the subjects who did not dark adapt (without mental work group) because of the probable drop in the corneoretinal potential. Rather, changes in form were scored.

Nystagmus and vigilance records (described later) were scored by different people who were unaware of individual scores on other dimensions. The scoring procedures reported in Appendix E were developed on records other than those employed in this experiment. The reliability results were calculated for records reported in this study, however.

Stimulus-response phase relations: Figure 4 presents an idealized drawing of nystagmus during sinusoidal oscillation. The point of zero slope of the eye position tracing, marked by "transition point" in Figure 4, is the point of zero slow phase velocity, and it coincides with the zero velocity of the stimulus. In a typical man, this phase relationship (zero velocity of the eyes coincident with zero velocity of the stimulus) could be expected to occur at frequencies approximately from 12 - 24 cpm (Niven et al., 1965; Wendt, 1936b) The present study used a 12 cpm stimulus frequency. Figure 5 shows eye movements

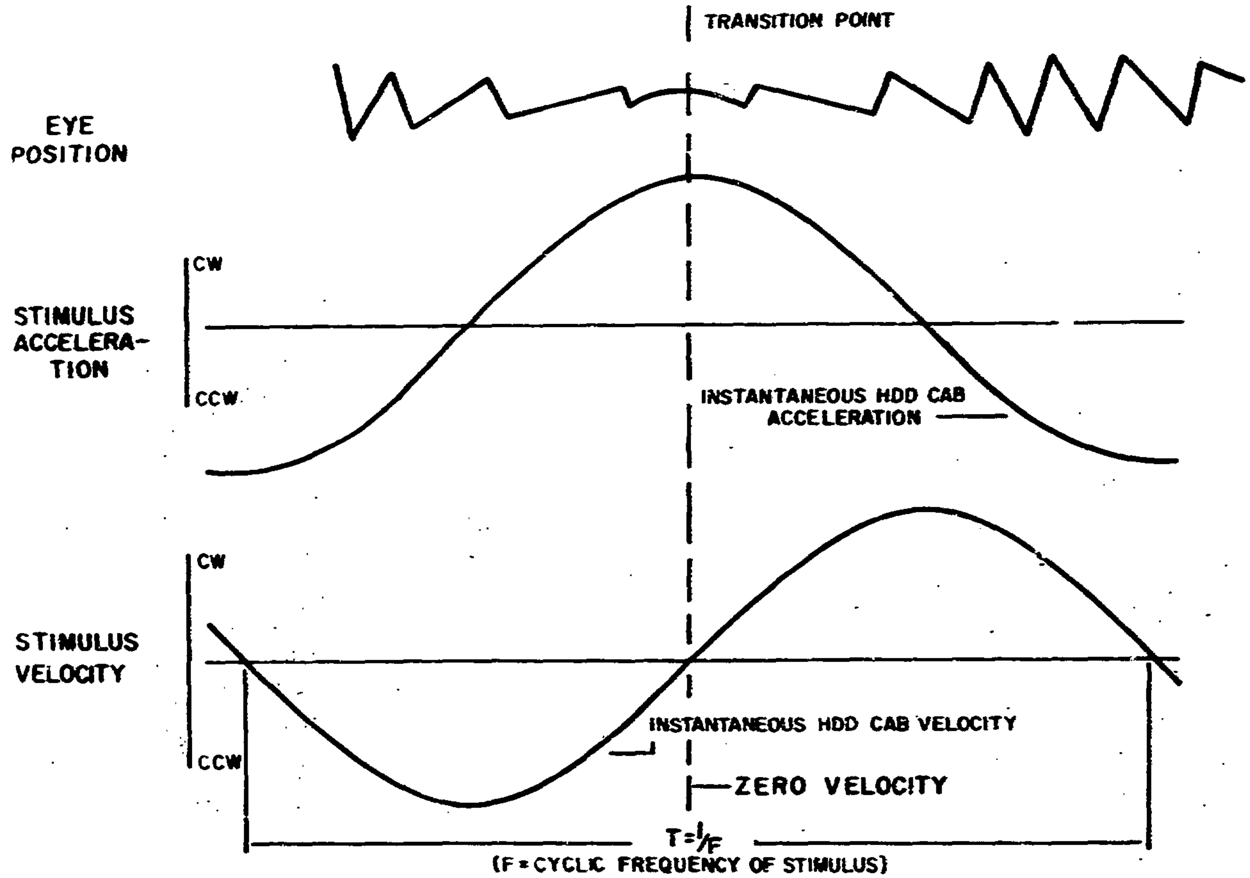


FIGURE 4. RELATIONSHIP OF IDEALIZED NYSTAGMOGRAM TO 0.3 CPS STIMULUS; REDRAWN AFTER NIVEN ET. AL. 1965

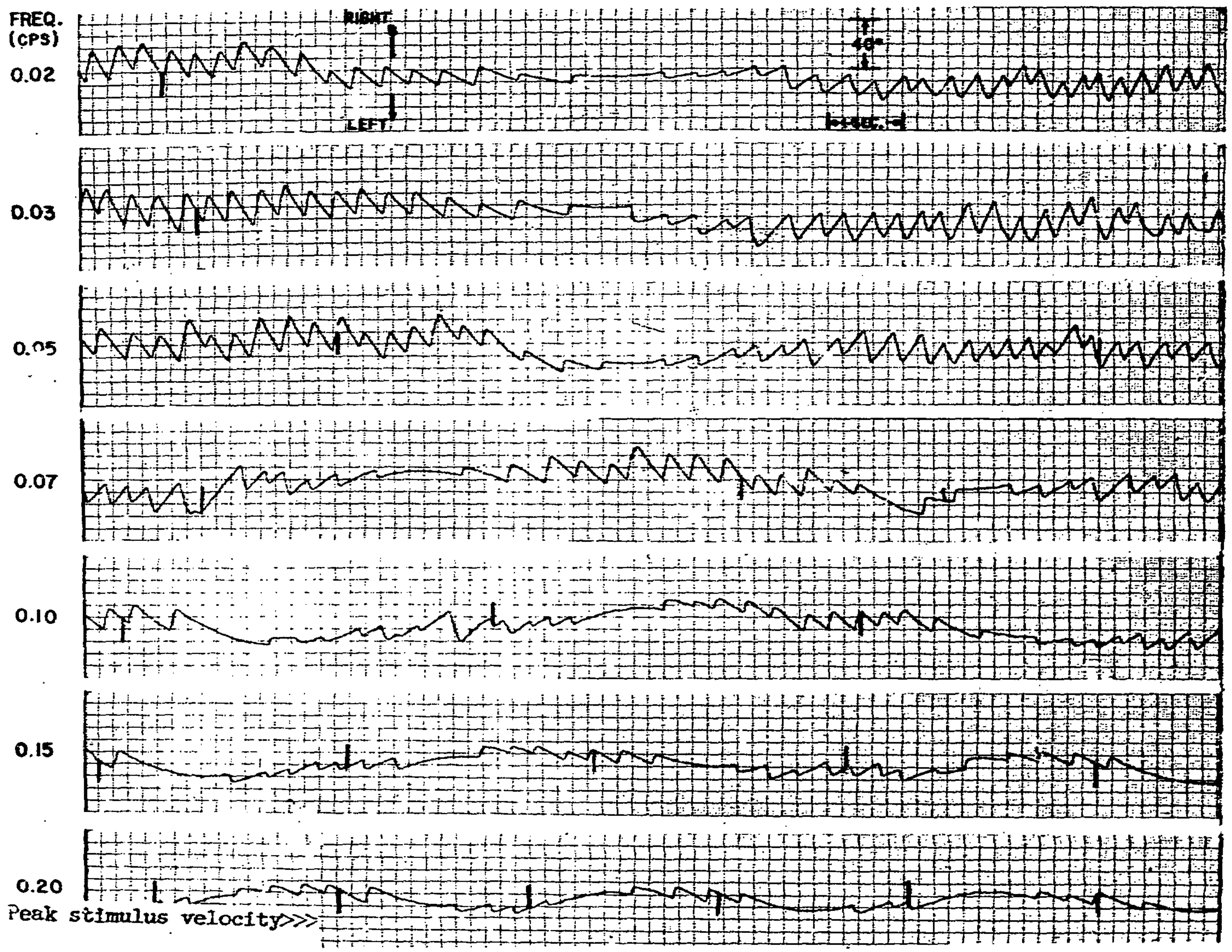


FIGURE 5. EXAMPLES OF NYSTAGMUS DUE TO SINUSOIDAL ANGULAR OSCILLATION AT DIFFERENT FRE FREQUENCIES AND FIXED DISPLACEMENT (AFTER NIVEN, ET. AL., 1965)

to different sinusoidal oscillation frequencies and frequency is reported in cycles per second (cps). Stimulus markers indicate peak velocity for each record. It may be seen that for 0.2 cps (i.e., 12 cpm) peak stimulus velocity coincides well with peak slow phase eye movement velocity and zero slow phase velocity (i.e., zero slope) occurs halfway between the peak stimulus velocity markers, or in other words, on the zero stimulus velocity.

Recording paper speed was set at 10 mm/second (therefore, there were 50 mm/cycle), and the phase angle (X) was calculated by the equation below as values of Y became known.

$$\frac{X \text{ degrees}}{360 \text{ degrees}} = \frac{Y \text{ mm phase angle}}{50 \text{ mm}}$$

More simply, since 1 mm was equal to 7.2 degrees, the obtained phase angle in mm was multiplied by 7.2 degrees to give phase angle in degrees. These values were calculated from several cycles within each five minutes for each subject's session of oscillation and averaged.

Voluntary eye movements: Electro-oculographic recordings were made of the voluntary lateral eye movements just before and just after the period of oscillation. The subjects were instructed merely to "...move your eyes back and forth". These eye movements were scored by measuring the duration for a complete cycle for several cycles and then averaged. A single complete sinusoidal oscillation cycle in the present experiment had a five-second period, since the frequency was 12 cpm.

<u>Vigilance task.</u> All subjects who received the vigilance test heard the same auditory signals for a 50 - 60 minute session. The signals were three tones recorded on a magnetic tape. The apparatus which originally generated the tones (and from which the tape was made) contained three cams ganged to a one rpm motor (see Figure 6). By tabs on each cam, a microswitch could be depressed. This triggered the tone[5] through an oscillator for that cam. Cams (channels) A, B, and C, had 5, 6, and 8 tabs, respectively, resulting in signal frequencies of 5, 6, and 8 per minute. All spaces between tabs were equal for Channels B and C, but for Channel A there was one double space (i.e., a missing tab). The combination of different signal pulse rates with one (slightly) aperiodic channel, resulted in a temporal distribution of tones which (according to subject's reports) seemed random, but the distribution was actually as it appears in Figure 7.

The auditory signals were presented to the subjects through standard Navy earphones at a comfortable listening level (ca. 60 db.). Channels A, B, and C had frequencies of 1800 H_z, 900 H_z, and 100 H_z, respectively. These were clearly audible and distinguishable.

The subjects received a ten-minute practice session on the task, which consisted of counting occurrences of low tones only. When the low tone had sounded four times, they pushed a key and began counting (the same tone) to four again; this process was repeated until the subjects were told to stop. During the experimental session, the subjects were also instructed to monitor the

[5] Spatially separate (one inch) lights can also be presented.

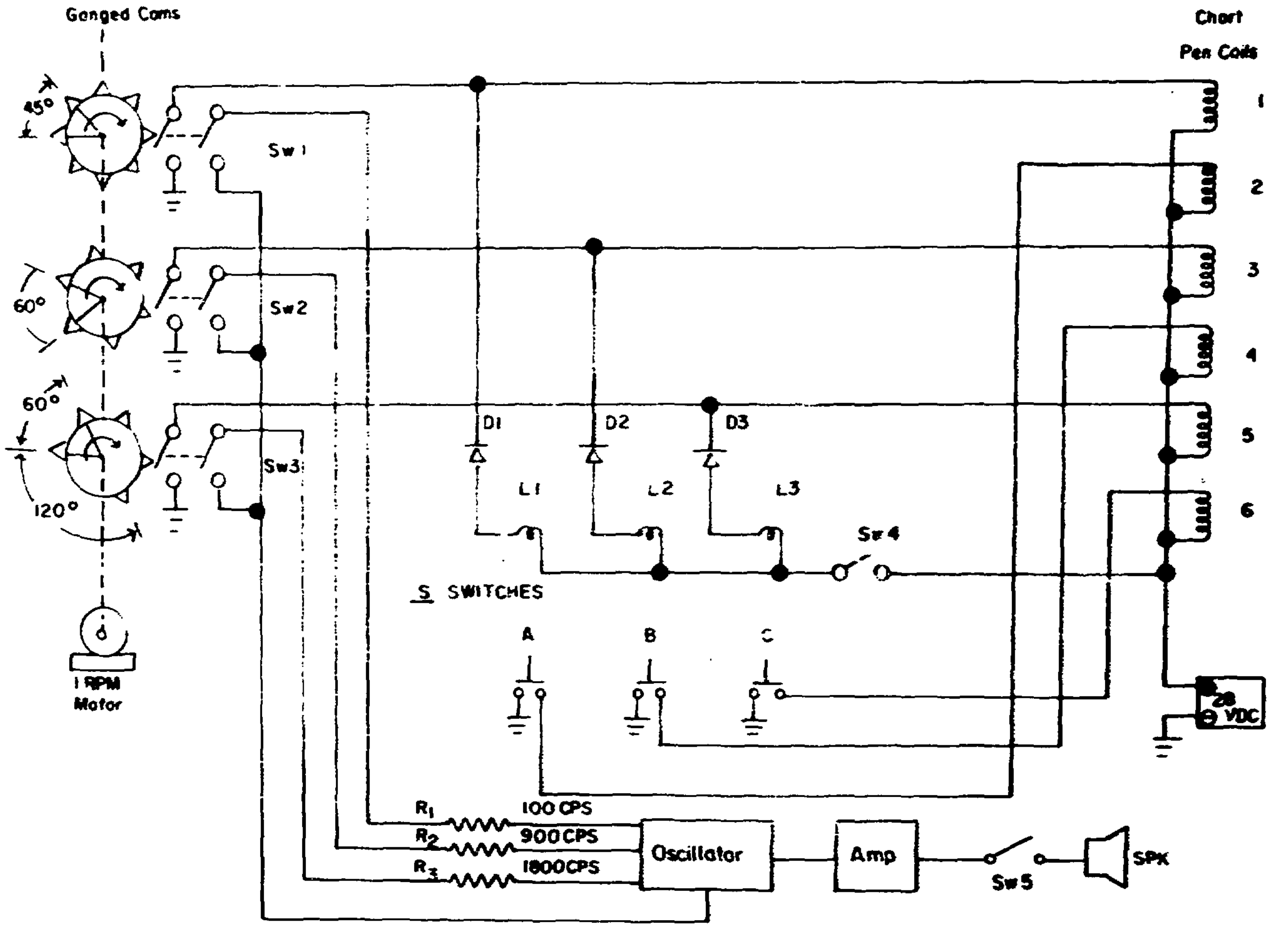


FIGURE 6. BLOCK DIAGRAM OF THE BAND-PASS ABILITY (B-PA) APPARATUS

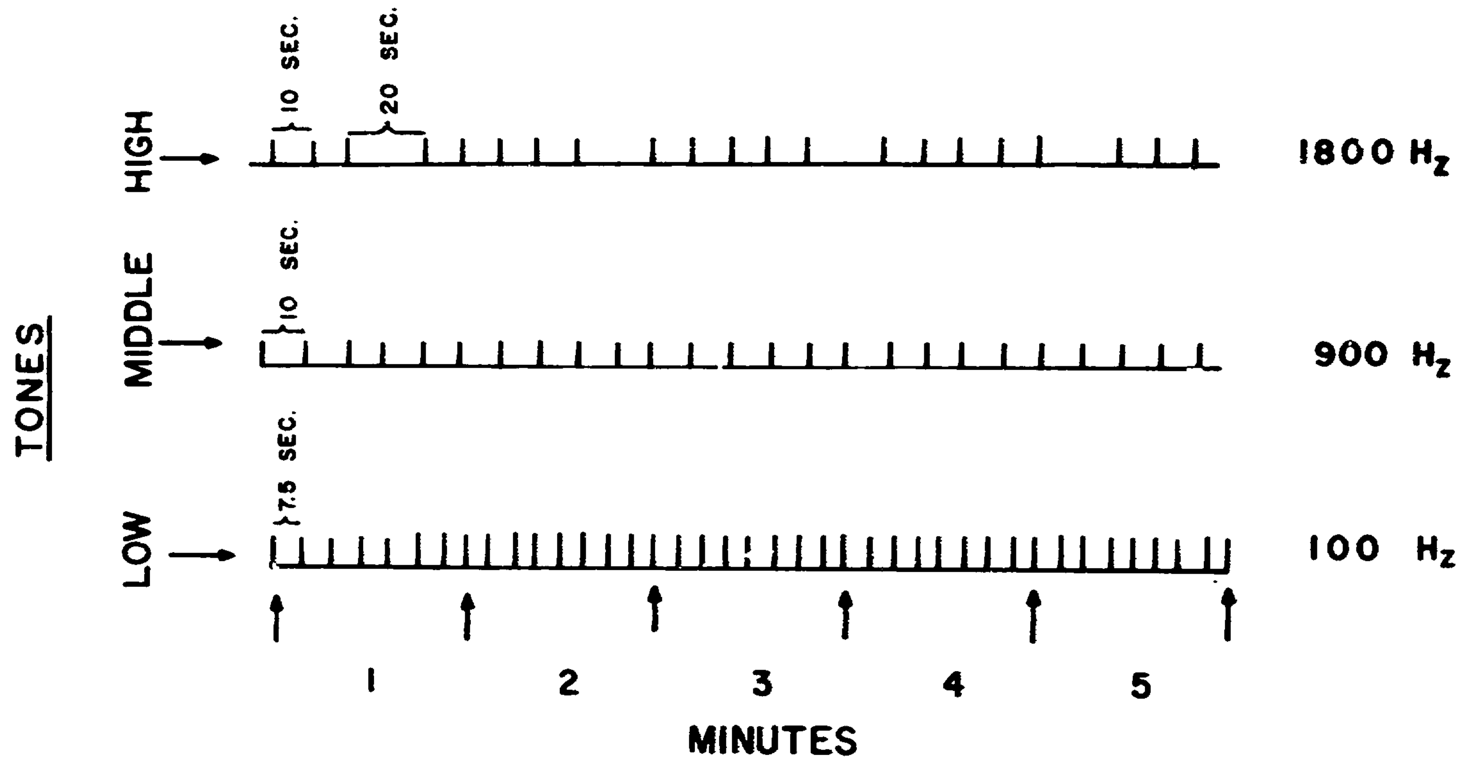


FIGURE 7. FIVE MINUTE SAMPLE OF TEMPORAL DISTRIBUTION OF TONES USED IN AUDITORY VIGILANCE TASK

middle tone in the same fashion, but to ignore the high tone. After the ten-minute practice session, they received a five-minute rest before being told to resume the task for an unspecified period of time. Group I subjects (N = 50) received all their testing individually in the dark while seated in the HDD. After practice, they performed on the task for 50 minutes while being oscillated and while eye movements were recorded. The other half (N = 50) were tested in an open lighted room, in groups of 8 - 12, for 60 minutes after their practice.

Vigilance scoring. Vigilance performance was scored in percent correct for each five-minute period. Errors of omission and commission were tallied separately, as were performances on middle and low channels. A previous publication (K nnedy, 1971) describes more completely the method of scoring, and also shows that the correlation of percent correct is linear (r = > .95) with "hits" and with "rights minus wrongs" (i.e., hits minus omission plus commission errors). The advantage of using proportion measures is that they permit comparisons of performances where different chances (signal rates) are employed. Because of the high correspondence between percent correct and absolute measures (i.e., hits), the usual shortcoming of a proportion measure (i.e., suspected non-linearity) probably does not apply in this case, and thus parametric statistical tests may be used. Additional findings obtained on this task appear in Appendix C and in Experiment II.

Pre-experimentation interview. A self-report questionnaire (Appendix D) which inquired about fitness, number of hours sleep, drugs, etc., was filled

out by all subjects prior to testing. Subjects with frank illnesses were not tested, and few illnesses were discovered. The subjects were all tested on their second or third afternoon (1330-1600) in the Navy. They reported an average of five hours sleep (SD less than two hours) and they responded with small dispersion on other questions. The homogeneity of this population and almost colony nature of their histories during the previous 24 hours (food, drink, drugs) should be emphasized.

Summary of procedure. In summary, 50 subjects each were assigned to one of three experimental conditions:

1. Individual persons were drawn from a classroom and transported to another labotatory where they were oscillated in the dark in the HDD for 50 minutes while they responded to an auditory vigilance task. This was preceded by 20 minutes of dark adaptation, during which there was ten minutes of practice on the vigilance test followed by a five-minute rest.

2. These subjects were also transported individually and were oscillated in the dark in the HDD for 30 minutes without formal control of mental state. This was preceded by about five minutes in the dark.

3. Groups of eight to ten men reported to an open classroom and responded to an auditory vigilance task for 60 minutes after ten minutes practice interspaced with a five-minute rest.

Results

Figure 8 shows the comparisons of vigilance performances for Groups I and III, who were tested with and without oscillation, respectively, as well as the nystagmus scores for Groups I and II, who were oscillated with and without a vigilance task, respectively. The difference in mean vigilance performance between the groups with versus without oscillation was not statistically significantly different, but the quality of the nystagmus of the group without a vigilance task decayed more rapidly than did nystagmus in the group who did mental work.

Figure 9 shows the performance of Group I, whose nystagmus was recorded during vigilance testing. Vigilance and nystagmus scores for the first five minutes were converted to 100%, and subsequent scores for each are proportions of the first. This was done to point out that both follow the same time course ($r = .93$). However, the relationship of these two effects to each other is stronger than the relationship of either to time. Also, their relationship to each other, with the effects of time partialed out, shows they still share 50% common variance ($r = .708$).

In order to determine whether the vigilance performance of a particular subject could be predicted from his nystagmus at any point in time, each subject's vigilance and nystagmus scores were correlated within a session. These correlations were then transformed to Z scores and averaged. The average of these correlations ($r = .27$) was significant ($P \quad .001$).

Another correlation was calculated for the 500 matched scores (50 subjects and ten five-minute time frames). This operation is open to question

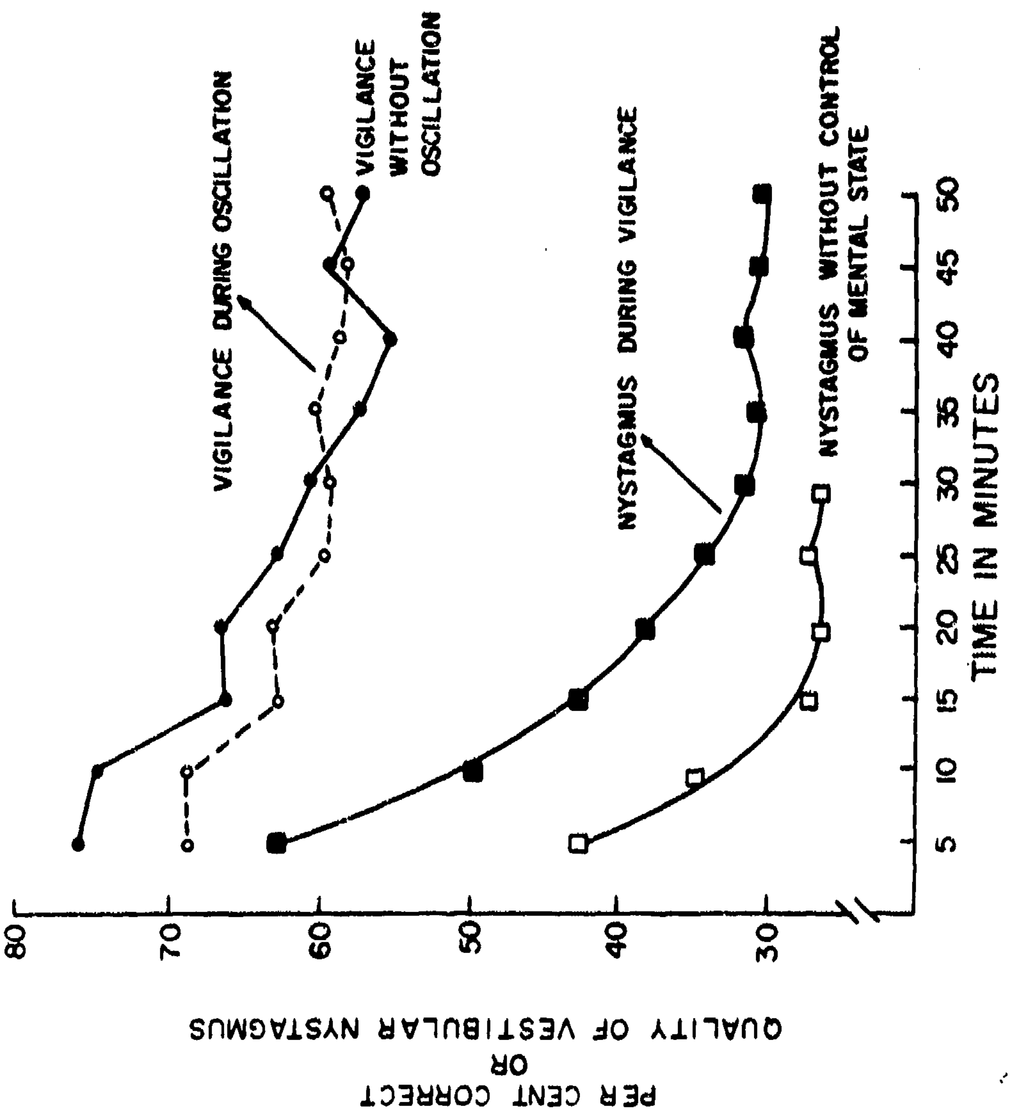


FIGURE 8. VESTIBULAR NYSTAGMUS AND VIGILANCE FOR THREE GROUPS OF NAVAL AVIATION PERSONNEL

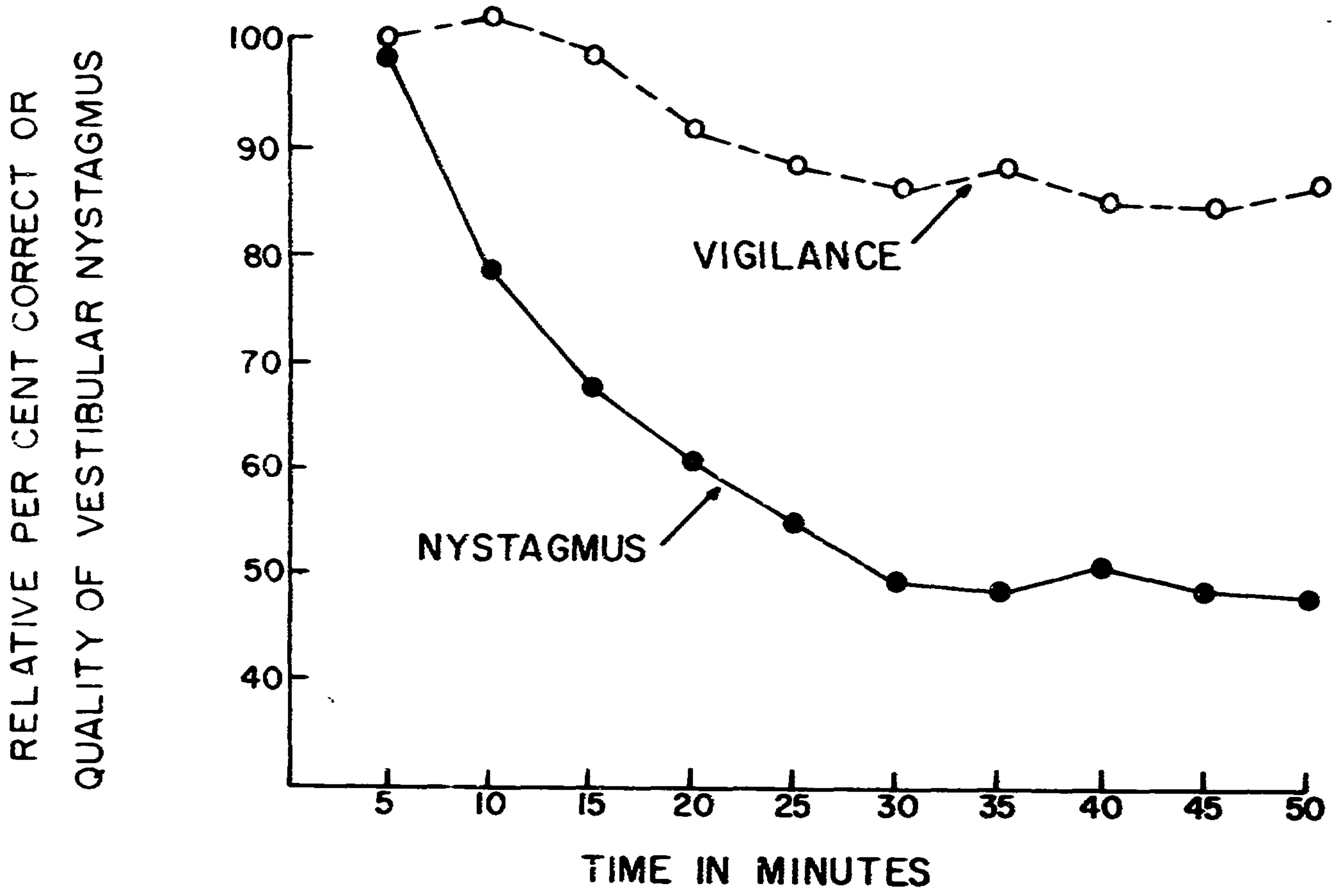


FIGURE 9. A COMPARISON OF TWO-CHANNEL AUDITORY VIGILANCE PERFORMANCE AND NYSTAGMUS HABITUATION FOR FIFTY SUBJECTS

since each of the ten scores within subjects are unlikely to be independent. However, the result can have a certain practical utility for an investigator who may wish to know with what accuracy he can estimate the alertness of his subject while viewing only his subject's nystagmus. The obtained value for the 500 paired scores is $r = .44$.

In two other treatments of the data, calculations were made of the mean and of the slope of each subject's nystagmus for 50 minutes, and the mean and slope of each subject's vigilance for 50 minutes. The scores were considered summary scores for nystagmus and for vigilance. The paired mean scores were correlated over the 50 subjects ($r = .46$, $P < .001$); the slopes were not.

Figure 10 shows the phase relationship of zero slow phase eye velocity to the stimulus in the two groups of subjects who were oscillated. The trend of the group without mental work (Group II) is significantly different from zero ($P < .05$) and from the group who responded to a watchkeeping test (Group I). The "with vigilance" group (I) showed no statistically significant trend. The phase angles in the group "without vigilance" became progressively earlier in time. The initial value of the phase angle was the average of the first five minutes, and was not significantly different from the expected value of 90 degrees in both groups, being 89.64 and 87.48, respectively, for the "with" and "without" vigilance groups. This phase angle eventually became approximately 75 degrees (a 14 degree shift) using the measurement convention adopted by Niven et al. (1965). This means, in effect, that the zero velocity of the response advanced relative to the zero velocity of the stimulus by 0.2

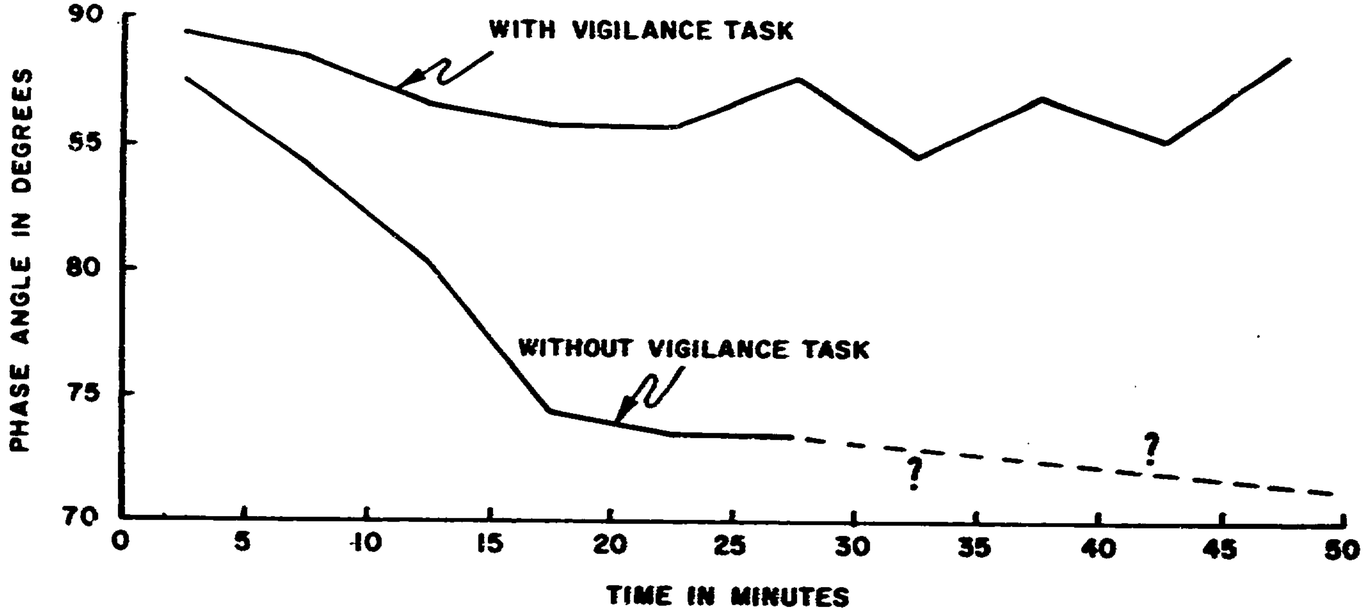


FIGURE 10. RELATIONSHIP (PHASE ANGLE) OF ZERO VELOCITY OF THE EYES TO PEAK VELOCITY OF THE STIMULUS FOR GROUPS WITH AND WITHOUT CONTROL OF MENTAL STATE

second.

Voluntary sweeping eye movements were recorded just before and just after oscillation. The average period of these movements post-oscillation (4.1 seconds) was not significantly different from pre-oscillation (4.6 seconds), and the period of those post-oscillations was less like the stimulus (5 second cycle) experienced during oscillation than those obtained prior to stimulation. Correlations were calculated between pre and post eye movements and the magnitude of a subject's habituation and his vigilance decrement. None of these correlations was significant.

Discussion and Conclusion

The main purpose of this experiment was to determine whether habituation of vestibular nystagmus could occur during mental work or whether vigilance was related to some characteristics of vestibular nystagmus habituation, and if vigilance and habituation would in fact covary.

The absence of fast phases was operationally defined as habituation, and under the experimental conditions that we used, a general correspondence existed between the quality of the fast phase and alertness as measured by a vigilance task. This correspondence supports what would be expected from other considerations: Collins, Crampton & Posner (1961), and Collins & Posner (1963) showed that nystagmus could be used as an arousal measure, at least as well as EEG's, and Daroff & Hoyt (1971) showed that fast phase nystagmus was absent in patients with massive lesions in the pontine reticular formation. Further, Pompeiano (Morrison & Pompeiano, 1965; Pompeiano & Morrison, 1965) showed that rapid eye movement sleep is abolished by ablation of the vestibular nuclei. In addition, the many studies cited by Guedry (1965) from the Fort Knox Laboratory, and the suggestions of the origin of the fast phase made by Gernandt (1959) and by McCabe (1965), and the overall control of the vestibular system by the reticular formation (Yules, Krebs & Gault, 1966) indicate that future studies should pursue further the generality of the relationship.

Other experiments which have shown other relationships between certain aspects of eye movements and the mental state of the subject are relevant to

the question of eye movements and arousal. These studies include (a) positive relationships between eye movements and visual imagination and recollection (Jacobson, 1930); (b) relationships between sensory deprivation, induced loss of arousal, and REM (Rossi, Furhman & Solomon, 1964); (c) relationship of EEG alpha and oculomotor activity with the suggestion that the latter causes the former (Mulholland & Evans, 1965, 1966); (d) changing pattern of fine eye movements during inattention (Gaardner, 1966); (e) relationships of eye movements to slow and fast paired associate learning (Haltrecht & McCormack, 1966); (f) positive relationship of voluntary eye movements to suppression of the visual evoked response (Gross, Vaughan & Valenstein, 1967); (g) relationship of fluctuation in visual perception to EEG and eye movements (Kirkwood, 1967); (h) negative relationships between vestibular nystagmus and rapid eye movement sleep (Reding & Fernandez, 1967); (i) superiority of saccadic over voluntary eye movements in adaptation to the Muller-Lyer illusion (Burnham, 1968); (j) the relationship of rapid eye movement sleep (REM) to EEG changes (Antrobus & Antrobus, 196[illegible]); (k) relationship between eye movements and brain stem reticular formation stimulation (Cohen, Feldman & Diamond, 1969); (l) relationships of electro-oculogram changes in anticipation of an operant response (Wasman, Morehead, Lee & Rowland, 1970).

From these studies and the results reported from the present study, it is felt that perhaps the fast phase of vestibular nystagmus can be used as a quantitative and independent index of arousal so that a person's performance in a job could be monitored without interfering with his work. Furthermore, other

forms of eye movements behave similarly and have a form similar to vestibular nystagmus. These movements include optokinetic nystagmus (Goodson, 1969; Pasik, Pasik & Bender, 1966; Wendt, 1965) and microsaccades (Riggs, 1958; Robinson, 1964). Some suggestive evidence is available from the saccadic suppression studies (Duffy & Lombroso, 1968; Matin & Pearce, 1965; Michael & Stark, 1967; Steinman, Cunitz & Timberlake, 1967; Volkman, Shick & Riggs, 1968) and from vestibular nystagmus studies (Zuber & Stark, 1966) where it has been shown that higher thresholds result just prior to the beginning of both forms of these eye movements (vestibular and microsaccades). Also, Guedry's studies (1968) of poorer visual acuity during vestibular nystagmus bear on this issue. The most obvious explanation of why visual information processing is less good during eye movements is that the image of an object is "smeared" on the retina when the eye is in motion (Dodge, 1900, 1905). However, while it is not possible to show in Guedry's studies in which part of the eye movement visual acuity is poorest, in the "saccadic suppression" studies the threshold is clearly elevated prior to the eye movement. This suggests if it does not prove that the suppression is more central than retinal and that the command signal for the quick flicks of the eyes in general (microsaccades and vestibular fast phases) inhibit the input before the eye goes in motion. A similar suggestion about suppression during voluntary eye movements was offered by Holt (1903).

For these and other reasons, the characteristics of eye movements hold promise for providing an independent measure of arousal. Some suggestions

for future research would be to replicate the present study wherein optokinetic, microsaccades and voluntary eye movements were elicited and measured. In such a study, characteristics of these eye movements (e.g., frequency, amplitude, velocity of flicks) could be empirically validated (between and within subjects) against a percent correct score on the auditory vigilance task. These findings could also be integrated, along with other supposed indicants of arousal (e.g., pupil size, heart rate, EMG, GSR, etc.). Multiple regression analysis (Brictson, Burger & Kennedy, 1971; Cohen, 1968; Kennedy, 1970) could be employed using performance on a task (in percent correct) as the criterion to be predicted. This approach, if successful, could then be generalized to other tasks.

It should be mentioned that three of the four statistical tests of the correlation of nystagmus and vigilance used in this experiment provide a very conservative test of the relationship between nystagmus habituation and vigilance decrement. The fourth method related the average amount of nystagmus habituation over subjects to the average percent correct over subjects for ten five-minute time frames. This correspondence was very high (r = 93), and while the latter is an accepted method of analysis in other studies (Daniel, 1966; Johnson, 1970, Lubin, Johnson & Austin, 1969), the relationship <u>within a subject</u> was also tested in three ways. All three remaining approaches were statistically significant, which indicates that a better than chance statement can be made about performance on a vigilance task in percent correct in an individual subject by knowing nothing else about him than his ongoing

vestibular nystagmus at that time. There are obvious sources of errors in the three approaches listed above, which if removed, could improve the relationship: (a) Individual differences in nystagmus do exist and if account could be taken of these, it is felt a better prediction could be made of arousal from a given person's nystagmus[6]; (b) percent correct has obvious shortcomings as a measure of the magnitude of mental work, since persons with high ability to do the task can obtain better scores than those with less ability who work just as hard. The average functional relationship with time course effects partialled out (i.e., $r = .708$) tends to minimize these two sources of error.

The results of this experiment show that the vigilance performances degraded similarly for Group I subjects who were oscillated individually in the dark, and for Group III subjects who performed as a group in the light without oscillation, while nystagmus habituation was more rapid when mental state was uncontrolled (Group II). The soporific effect of motion (particularly sinusoidal motion) is well known, and may be the cause of the greater habituation of the oscillated group in the first 30 minutes of their session. However, a large literature exists in vigilance (Buckner & McGrath, 1963; Davies & Tune, 1970; Mackworth, 1970), and the degraded performance is probably due also to the simple loss of arousal which occurs in connection with repeated stimulation. Mackworth (1968, 1970) has attempted to assign a similar basic process to explain both habituation to stimulation (Thompson & Spencer, 1966) and the

[6]Reviewing an entire nystagmus record before scoring each cycle is helpful in this regard.

vigilance decrement (Broadbent, 1964; Buckner & McGrath, 1963).

The difference in habituation of vestibular nystagmus when mental work was controlled by the vigilance task, versus when it was uncontrolled, indicates that the vigilance task served in part to retard the nystagmus habituation.

Phase shifts of vestibular nystagmus during long term oscillation were studied in an alerted and unalerted group. No statistically significant change occurred in the group which attended to auditory signals, although the slope was slightly negative. Further, the vigilance performance and nystagmus of that group did degrade (cf. Figures 8 and 9). In the group without control of mental work, however, the phase angle changed significantly over time. Yet the change was not in the direction that one might expect to occur in connection with lowered alertness (viz. increased latency). Rather, a 14-degree phase advance relative to the baseline resulted. This appears to be an anticipation of the stimulus by the slow phase of nystagmus, an unusual finding when compared with the knowledge that attempts to condition the slow phase have been unsuccessful (Wendt, 1936b, 1951).

It is felt that this time X alertness relationship should be an important consideration in studies of the frequency response of the semicircular canals, and Niven (et al., 1965) take care in controlling mental state when they conduct their studies. However, the systematic negative correspondence between level of alertness and progressively earlier phase angle is not an easy result to explain. Support for the results of the present study appear in studies by Jones (1971) where a phase advance appears in cats as they recover from

ether anesthesia. A similar result may also be observed in the records of Wolfe (1967, Figure 2).

The finding in the present study of a phase advance during oscillation without mental occupation remains largely unexplained, although it is probably not an artifact. For example, Barlow (1969) has also shown a similar result for "eyes closed in the dark during sinusoidal oscillation" when compared to "eyes open in the dark during sinusoidal oscillation". In the present study, the subjects reported that their eyes were open throughout as instructed, and they appeared also to respond to small, dim stimuli (fixation lights) when the latter were presented.

Since the presence of efferents (Sala, 1964, 1965) is well established for the vestibular system, it is felt that a central explanation of the phase advance effect might employ this pathway. Another explanation is peripheral and takes the position that with time, and more specifically, decreased alertness, the characteristics at the end organ or at the first synapse change (Young, 1969, personal communication) so that a velocity transducer becomes more like an angular accelerometer. This factor should be considered in the theoretical models of semicircular canal functioning.

Experiment I, Part 2

Individual Differences in Nystagmus Habituation and Vigilance

Introduction

The second aspect of this investigation was to examine individual differences in habituation, as manifested by vigilance and nystagmus changes, in relation to other measures such as personality and exposure history (e.g., hours sleep). These individual differences would be studied as correlates, and not merely dispersion. There were two major dichotomous phenctypic continua which appeared relevant and practical: (a) The introvert-extravert of Eysenck (1952, 1953, 1957, 1964); and (b) the field dependent - field independent of Witkin (1949; Witkin, Dyk, Faterson, Goodenough & Karp, 1962; Witkin, Lewis, Hertzman, Machover, Meissner & Wapner, 1954). A very large literature exists for both and for the numerous correlates of these phenotypes, the reader is referred to the works of Witkin and Eysenck.

The suggestion of the relationship between field dependence and lack of nystagmus habituation comes from Wendt (1951). He claims that in "...human subjects *properly instructed and stimulated*, alertness can be maintained for continuous ten-minute periods of recording. The trick is to *maintain an environment directed orientation*" (p. 1215; italics mine). The picture that Witkin presents of a field dependent subject is of a person who is suggestible and who follows instructions, and he is a person who cannot give up the field[7], even when it

[7]A finding by DeFazio & Moroney (1969) suggests that "the field" is most likely a visual field and not all fields.

is proven to be non-veridical (Witkin, 1949). The incidence of field dependence is high in the very young (Witkin et al., 1962) and the very old (Karp, 1966), the latter suggesting that perhaps flexibility or adaptability is involved. This notion appears to be supported by the results of Haronian & Sugarman (1966), which show that field dependents are not resistant to Necker Cube reversal, even when instructed to be resistant, plus field dependents are "fixed" versus "mobile" on the "fixity vs. mobility" dimension of Werner (cited in Haronian & Sugarman, in press). Poorer ability to adapt by field dependent persons may also be reflected in the studies of Immergluck (1966a, 1966b) where field dependents produce fewer figural aftereffects and less figure-ground reversal. One may also interpret their poorer performance (less mature) in sensory deprivation (Murphy, 1966) as being due to an inability to inhibit a response, or to increased activation. It is felt, therefore, that if nystagmus habituation would be less in field dependent subjects, the persistence would be due to the basic inability of these subjects to give up a "field".

Paper and pencil measures of introversion have had much more popularity than Witkin's (1949) individual situational testing, and a larger literature exists for introversion[8]. Eysenck (1957, p. 28) lists 21 important introversion correlates and supports each with literature citations. The correlates with introversion of interest for this discussion include (a) high perceptual rigidity;

---

[8] It is this author's opinion that this ratio is changing, partly for reasons discussed _para passim_ in this paper.

(b) small figural aftereffects[9]; (c) high sedation threshold and (d) quick to acquire a conditioned response. Lynn (1966) reports also that they extinguish slowly and have a slow buildup on inhibition. In addition, Kottenhoff (1957, 1958) has shown that introverts are more susceptible to motion sickness than extraverts, and that they adapt to prismatic distortion less well. One other result bears mention: Introverts tend to show less decrement in performance on a vigilance (i.e., watchkeeping) task, than normals and extraverts, according to Bakan (1963), Bakan, Belton & Toth (1963), Broadbent (1958) and Buckner (1963).

The latter result with vigilance requires additional exposition. The vigilance paradigm generally requires that a subject monitor some display which presents low amplitude signals infrequently. The typical result is that most persons perform less well over time (i.e., they miss signals), and extraverts are relatively less vigilant. A good review of this literature appears in Buckner & McGrath (1963), Davies & Tune (1970) and Mackworth (1970). The possibility exists, however, that since many real world jobs are different from laboratory tests of vigilance, perhaps on a more complicated vigilance task (e.g., the II channel test as described in Experiment I), personality scores may interact with task complexity.

In addition to the self report variables from the pre-experimentation

---

[9] The characteristics of introverts and field dependents suggest that these phenotypes should correlate high with each other. A literature review revealed one study (Evans, 1969) where a slightly negative relationship was obtained, and another (Franks, 1956) where no relationship was found. Witkin (personal communication, 1970) also predicts a negative relationship.

interview (cited in Experiment I, Part 1, and shown in Appendix D), it was decided to determine whether selected personality scores were correlated with vigilance decrements and with nystagmus habituation.

Apparatus and Procedure

The Eysenck Personality Inventory Form B (Eysenck & Eysenck, 1963) was used to obtain extraversion and neuroticism scores. The Group Embedded Figures Test cf-1 (Evans, 1967; French, Ekstrom, Leighton & Price, 1963; Jackson, Messick & Myers, 1964) served as the measure of field independence; the title page appears in Appendix D. Both are described in more detail and norms are presented in Appendix A. These tests were administered by a proctor to entire classes of student aviation personnel nine weeks after some of them served as subjects in Experiment I, Part 1. It is unlikely that subjects would connect participation in both parts of the study.

The pre-experimentation interview was completed just prior to nystagmus and vigilance testing. Means, standard deviations (SD), and slopes (b) of vigilance and nystagmus over time served as the chief measures of performance. Pearson product moment correlation coefficients were calculated for the variables.

Results

General. Table 1 compares the means and SD's of the subject exposure history variables, personality scores and performance variables for these groups. It may be seen that the subjects considered themselves fit and healthy. They had no drugs (including analgesics) in the past 24 hours, and those who responded that they had had a drug were reporting a routine tubercular skin test (PPD). They had virtually no cigarettes in the last four hours and almost no one had alcohol for 24 hours. This question was dropped in subsequent analyses. The subjects' concern for their performance was moderate, and most subjects felt they would perform better than average[10]. Most of the subjects did not consider that the number of hours they had slept was adequate (5.20 hours). However, the correlation of hours slept with the subject's estimate of the adequacy of his sleep (Tables 3 and 4, discussed later) were significant, but very low. This type of inconsistency is probably to be expected in connection with young men's initial exposure to barracks life.

The homogeneity of the population and the low variability on the pre-experimentation interview responses can be expected to reduce the chances of prediction of other performances from these responses. However, it should be emphasized that this low variability is also a testimony to the control for the exposure history of these subjects.

---

[10] The pre-experimentation interview was developed in connection with motion sickness studies by the author. Although the intention was to develop an all purpose questionnaire, some questions may be more or less appropriate depending on the experimental treatments.

TABLE 1

Means and Standard Deviations for Pre-Experimentation Interview, Personality Test Scores, Nystagmus Habituation, and Vigilance Performance for Three Groups

Variable	Question No.	Scoring Code	Group I Nystag + Vig N = 50 Mean	SD	Group II Nystag Only N = 60 Mean	SD	Group III Vig Only N = 46[a] Mean	SD
1. Any Illness	1	No=2; Yes=1	1.96	.20	1.95	.22	1.88	.32
2. Usual Fitness	2	Yes=2; No=1	1.76	.43	1.86	.34	1.77	.42
3. Alcchol	3a	None=2	1.96	.20	1.98	.13	2.00	.00
4. Cigarettes	3b	None=2	2.00	.00	2.00	.00	2.00	.00
5. Other Drugs	3c	None=2	1.86	.35	1.80	.40	1.94	.23
6. Sleep	4a	Number Hours	4.79	1.75	5.58	1.42	5.67	1.16
7. Sufficient	4b	Yes=2; No=1	1.16	.37	1.58	.49	1.48	.50
8. Concern	5	None=1; Great=5	3.22	.90	3.91	1.09	3.34	.94
9. Expectation	6	Better=3; Poorer=1	2.52	.83	2.60	.80	2.03	1.00
10. Food	7a	Hours Since	2.56	.87	1.87	.96	1.71	.81
11. Fluid	7b	Cups Recently	2.31	1.76	2.43	1.55	3.94	2.12
12. Field Independence			13.84	5.48	14.82	5.26	13.21	6.41
13. Extraversion			16.82	2.75	16.23	3.01	16.63[b]	2.48
14. Neuroticism			6.26	3.38	5.85	3.71	6.45[b]	3.01
15. Lie Score			1.70	1.10	1.67	1.65	1.01[b]	1.43
16. Vigilance Slope			-.13	[illegible]			-.15	.21
17. Nystagmus Slope			-.31	.22	-.74	.89		
18. Mean Nystagmus			38.05	17.63	34.13	16.95		
19. SD Nystagmus			12.31	6.46	14.25	5.87		
20. Mean Vigilance			62.29	15.47			63.18	19.09
21. SD Vigilance			11.21	4.36			14.89	5.87

[a] N=35 for Pre-Experimentation Interview Items (VB 1-11)

[b] These subjects received Form A of this test. The equivalent scores for Form B were calculated from the Test Manual and are reported here.

The mean values of the personality test scores are compared with a reference population in Table 2; none are statistically different from those reported in more detail on the larger sample in Appendix A. The group specific nystagmus and vigilance performances were discussed in Part 1.

Pre-experimentation interview and performance. Correlation matrices for pre-experimentation interview responses, personality scores, and vigilance and nystagmus variables were calculated for Group I (nystagmus measured during vigilance testing). These results (Table 3) generally showed relationships in a predictable direction, but for the most part the correlations were not significant. An exception was the correlation of a report of good health and good vigilance performance. A correlation matrix (Table 4) was constructed for Group II (nystagmus/no vigilance) to see whether similar items were predictive of nystagmus habituation in the two groups who were oscillated. In this attempt at cross validation, no item was found to be significantly related to performance in both groups, even when a liberal test was applied ($P < .10$; one tail). Missing pre-experimentation interview data (ten forms) for Group III (vigilance/no nystagmus) precluded including history data in Table 5, since the sample size was reduced to a point where there would be half as many variables as subjects. Therefore, Table 5 only contains the relationships of vigilance performance to personality scores.

Personality test scores and performance. Tables 3, 4 and 5 show also the relationships between experimental variables and personality test scores. The interrelationships of personality test data alone are covered in Appendix A.

TABLE 2

Mean Personality Test Scores for a Large Reference Population of Student Personnel Vs. the Three Experimental Groups Combined

	Reference Group		Experimental Group	
	Mean	SD	Mean	SD
Field Independence	13.92	6.07	14.08	5.62
Extraversion	16.64	2.94	16.53	2.78
Neuroticism	5 98	3.70	6.14	3.45
Lie Score	1.53	1.48	1.51	1.41
N	1838		155	

TABLE 3

Correlation Matrix of Experimental Variables for Group I (Nystagmus plus Vigilance)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Illness		.12	-.17	-.19	.05	.13	.01	.09	-.21	.17	.05	.04	.37	.12	.04	-.19	.26	-.38
2. Fitness			.39	.12	-.07	-.10	.23	-.33	-.05	-.36	.20	-.07	-.12	-.28	.22	.24	-.10	.07
3. Hours Sleep				.30	-.06	.13	.05	-.41	-.07	-.15	.05	-.08	-.09	-.27	.25	.20	.24	.00
4. Sufficient					.14	-.01	-.22	.12	-.00	.01	-.20	-.13	.03	-.20	.00	.14	.03	-.11
5. Concern						-.05	.23	.05	.20	.01	.23	-.18	.00	-.09	.02	.05	.12	-.13
6. Expectation							-.60	-.27	-.32	.05	.20	.04	.04	.13	-.01	-.17	-.05	.01
7. Food (Hours)								-.46	.06	-.13	.02	.12	-.21	.03	-.13	.11	-.26	.11
8. Fluid (Cups)									-.19	.25	.07	-.03	.21	.12	-.02	-.18	-.06	-.08
9. Field Independence										-.25	-.08	-.07	-.14	-.20	-.10	.22	.17	-.01
10. Extraversion											-.11	.06	.18	.04	-.32	-.07	-.00	-.00
11. Neuroticism												-.25	.05	.18	.01	-.20	-.08	-.02
12. Lie Score													.02	.08	-.15	-.11	-.09	.06
13. Vigilance Slope														.09	.03	-.17	.27	-.70
14. Nystagmus Slope															-.21	-.91	-.14	-.05
15. Mean Nystagmus																.15	.46	-.12
16. SD Nystagmus																	.09	.16
17. Mean Vigilance																		-.47
18. SD Vigilance																		

When N = 50 – $r_{.10}$ =.24*; $r_{.05}$ = .28; $r_{.01}$ = .37; $r_{.001}$ = .47

*Two-tailed significance values of r for $P < .10$.

TABLE 4

Correlation Matrix of Experimental Variables for Group II (Nystagmus Only)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Illness		-.09	.20	-.04	.05	.27	.01	-.02	.14	-.01	.01	-.28	-.11	.04	.00
2. Fitness			.33	.37	.01	-.20	-.13	.07	-.05	-.12	-.14	.10	-.02	-.01	-.07
3. Hours Sleep				.35	.05	.26	-.22	.15	.05	.11	-.17	.02	-.02	-.01	.06
4. Sufficient					-.07	-.09	-.07	.09	.04	.11	-.25	.12	.02	.12	.03
5. Concern						.42	.08	.01	-.09	-.38	.18	.19	.05	-.04	.06
6. Expectation							.08	.11	.11	.04	-.11	.00	.15	.07	.06
7. Food (Hours)								-.07	.05	.04	.02	-.08	.11	.07	-.09
8. Fluid (Cups)									.08	-.00	.05	.10	-.19	.09	-.19
9. Field Independence										-.07	-.02	[illegible]	-.02	-.07	-.13
10. Extraversion											-.52	[illegible]	.11	-.02	.02
11. Neuroticism												-.15	-.08	-.08	-.05
12. Lie Score													.17	-.02	.24
13. Mean Nystagmus														.15	.15
14. SD Nystagmus															-.15
15. Nystagmus Slope															

Where N = 60 - $r_{.10}$ =.23*; $r_{.05}$ = .26; $r_{.01}$ = .34; $r_{.001}$ = .43

*Two-tailed significance values of r for $P < .10$.

TABLE 5

Correlation Matrix of Experimental Variables for Group III (Vigilance Only)

Variable	1	2	3	4	5	6	7
1. Field Independence		-.50	.20	.01	.20	.11	-.10
2. Extraversion			-.06	.18	-.16	.01	.00
3. Neuroticism				-.21	.07	-.05	-.11
4. Lie Score					-.03	.01	.13
5. Mean Vigilance						-.48	.33
6. SD Vigilance							-.78
7. Vigilance Slope							

Where N = 46 – $r_{.10}$ = 25*; $r_{.05}$ = .29; $r_{.01}$ = .39; $r_{.001}$ = .49

*Two-tailed significance values of r for $P < .01$.

The relationship of field independence and nystagmus habituation in Tables 3 and 4 (slope of nystagmus) was in the predicted direction on both occasions (field independents habituate more), but neither was significant. Extraversion was related to the mean of nystagmus in Table 3 ($P < .05$), but the sign of the relationship changed in Table 4.

Tables 3 and 5 can also be used to compare vigilance relationships. Correlations of field independence scores were positive with mean vigilance, but negative with slope (i.e., larger decrements for field independent subjects), but none of the four relationships was significant. Extraversion was not correlated with the slope (i.e., decrement) in Table 5, but in Table 3 there was a suggestion that extraverts had less decrement (negative slopes), but this relationship was insignificant.

In Tables 3 and 5, the slope variances are largely accounted for by their respective standard deviations[11]; this was not the case in Table 4. In Table 3 the vigilance and nystagmus session means were correlated ($P < .01$), but the slopes were not.

[11]This is not unusual in view of the relationship $b_{12} = r_{12} \frac{SD_1}{SD_2}$

Discussion and Conclusions

General. The pre-experimentation interview was administered to monitor the exposure history (in the previous 24 hours) of the experimental subjects and also to determine whether these subject variables were related to nystagmus habituation or vigilance performance. Although there was a general agreement between the hypothesized direction a response was to take (on the pre-experimentation interview) and the nystagmus and vigilance data, these relationships are of doubtful significance and small importance. On the other hand, if the low variability as shown in the pre-experimentation interview is valid (Hardacre & Kennedy, 1963, among others, have evidence these men tend to be truthful), it is a useful finding in interpretation of data obtained from this population because it represents control for the influence of history variables on experimental treatments. Stated differently, it appears that samples from this population may be considered essentially equivalent, so that for many research efforts, it is not necessary to use each subject as his own control. The practical implications for the conduct of repeated measures studies are important. In such studies, subjects often miss sessions, with the result that often the sample size shrinks each session to a level where eventually an adequate test of the hypothesis cannot be made. A more complete description of the shortcomings of the typical correlational experimental paradigm appears in Cronbach (1957) and Owens (1968); Owens advocates an approach similar to what was accomplished in the present experiment to provide "...laws [which] should be more meaningful and the description of subjects to whom they apply

more complete and definitive" (p. 784).

Individual differences and vigilance. Field Independence: In the first part of this study, it appeared that nystagmus habituation and vigilance decrements covaried. In the second part, it was hypothesized that the nystagmus of field independent persons would habituate relatively more quickly. It follows, therefore, that their vigilance (slopes) should degrade more quickly, also. Although neither test of this hypothesis was significant, both were in the predicted direction, even though both mean scores and field independence were positive, but insignificant. This means that while persons with high field independent scores tended to higher overall vigilance scores, their decrements tended to be larger also. It is felt that these data suggest that future study of field independence scores and sustained attention is warranted, particularly when considered with the nystagmus habituation relationships to be discussed later.

Extraversion: The vigilance data presented above failed to support the findings reported by others regarding less decrements in performance of introverts (Bakan, 1963; Bakan, Belton & Toth, 1963, Broadbent, 1958, p. 145 ff; Buckner, 1963). In fact, the correlation was in the opposite direction (extraverts tended toward better vigilance slope scores), but was insignificant (Table 3). This inability to replicate may be due to several factors:

1. Most previous findings were obtained by comparing extreme introverted with extreme extraverted groups; the present study utilized all subjects.

2. As a group, the subjects in the present study were extraverted (mean 60th percentile) and the sample was also restricted in range. Both of these

factors have been reported (Buros, 1965, item 138) to have influenced findings in previous experiments.

3. In other vigilance studies (cf. Buckner & McGrath, 1963) performance for segments (often 30 minutes) in an experimental session (often 90 minutes) are used to test for mean differences between groups, whereas in the present experiment, a summary score each five minutes could be calculated for each subject so that a slope score for <u>each subject</u> could be used to describe performance. This score was then compared to subject's personality scores. It is felt that this is a more informative test of a suspected relationship than testing mean differences in extreme groups. However, by using the entire distribution, it also depends heavily on the reliability of both scores[12]. The paper and pencil test of extraversion used in the present study is of questionable reliability (cf. Appendix A). In addition, a slope score ignores the level at which a person can respond, except to the extent that slope is dependent upon the initial level. Thus, when using slope as an index of performance, the "ability" to do the work is partialled out, and conceivably two subjects with very different mean scores can both degrade at the same rate and obtain the same slope score. Conversely, the same mean can be obtained by persons with different slopes. It is felt that slope is a better measure than the mean of the vigilance on a task because the slope indicates how well a person performs over time, whereas the mean is partly due to how well a person can do

---

[12] Appendix A reports a correlation between extreme extravert scores and extreme field independence scores.

the work (viz., ability) and how well it is done over time (vigilance). Which measure should be used to assess vigilance performance in particular experiments can be determined by the strategy of the experimenter's study. This will not necessarily always be the same measure. For example, a "miss", a "hit", or the "level of performance over time" may at different times be of more or less relative interest. However, if vigilance as a trait, characteristic, or life style variable is of interest, it is suggested that the slope of performance or some other measure of change over time (e.g., proportion of the decrement) would be a more valid index of vigilance than is presently employed in the vigilance studies in the literature.

4. Perhaps most important, the general paradigm of vigilance experiments (Broadbent, 1964; Buckner & McGrath, 1963) involves presentation of infrequent near-threshold signals for detection. The present study used frequent supra-threshold tones in two channels, and required the subject to perform more complicated mental work than merely detecting the presence of a signal[13] and perhaps task complexity and personality interact.

A behavioral theory of individual differences in vigilance. Broadbent's (1958) comments about the programming of a translating machine are relevant to the possible interactions between task complexity and an individual's style

[13] Indeed, the task in this study doesn't meet Broadbent's definition of a vigilance task. However, it is felt also that the kind of work in the present study has more application to the kinds of work that persons do in the real world, and that Broadbent's definition is too restrictive.

or personality of information processing. He suggests that a translating machine can be set up to print out (i.e., transcribe) when a letter, a word, or a sentence is fed in. Depending on the work to be performed, there can be an advantage to one or the other program. Thus, in the translation of a code, where each letter has a different symbol in the same language, there is no advantage to waiting for a complete sentence. If, on the other hand, the translation is of English to Russian, for example, then it would be better for the machine to hold entire sentences or even paragraphs before printing out, since the syntax of the two languages is so different. The following is a modification and extension of Broadbent's notions:

Perhaps some people are differentially able to sustain attention to simple tasks for a long time. If such persons can be identified, it is felt that they would be better able to pay attention for a long time on a simple watchkeeping task. Because all information is sampled in time or space, perhaps another class of persons exist who have a predisposition to process information delivered over the latter dimension (i.e., space). Furthermore, perhaps these traits are negatively correlated. Thus, the converse of a person who could sustain attention for a long time on a simple test would be a person who could pay attention to many things at once, but he may not necessarily do well over time, particularly if he assigned all his effort (channel capacity) to the time dimension. If these traits exist and are in fact separate, i.e., you may be one kind of person or the other, and this trait is different from the construct

channel capacity[14] or intelligence, then it might be possible to assess this trait experimentally by constructing tasks which test for sustained attention versus multiple inputs at once. It may be illustrative to consider acuity in vision and audition. For example, in Figure 11 the eye is shown with superior spatial acuity compared to the ear, and the ear with superior temporal acuity compared to the eye. Yet, the overall information processing ability (cf. channel capacity) of both could be the same (hypothetically shown here by equal areas). An advantage would be observed for vision if spatial resolution were tested, and for the ear if temporal acuity were tested; yet the total resolution capability over time and space together could be equal for the two systems. If the overall information processing capability (e.g., channel capacity) is fixed in some way, then the only way to improve spatial acuity, for example, would be at the expense of temporal acuity and the converse. If people develop or were born with different information processing styles (personalities), then conceivably they may also be predisposed to process one kind of displayed information at the expense of another. Perhaps there are two traits in people: The ability to monitor few things (e.g., one channel) for a long time, and the ability to monitor many things (e.g., channels) for a short time. Figure 12 shows two extreme persons and one mixed person, all with the same channel capacity. The person who presumable can monitor for a longer period of time is a person referred to as a long term sampler; it is expected that he would

[14] Defined here as the aggregate number of bits of information that can be processed when presented over available channels per unit time.

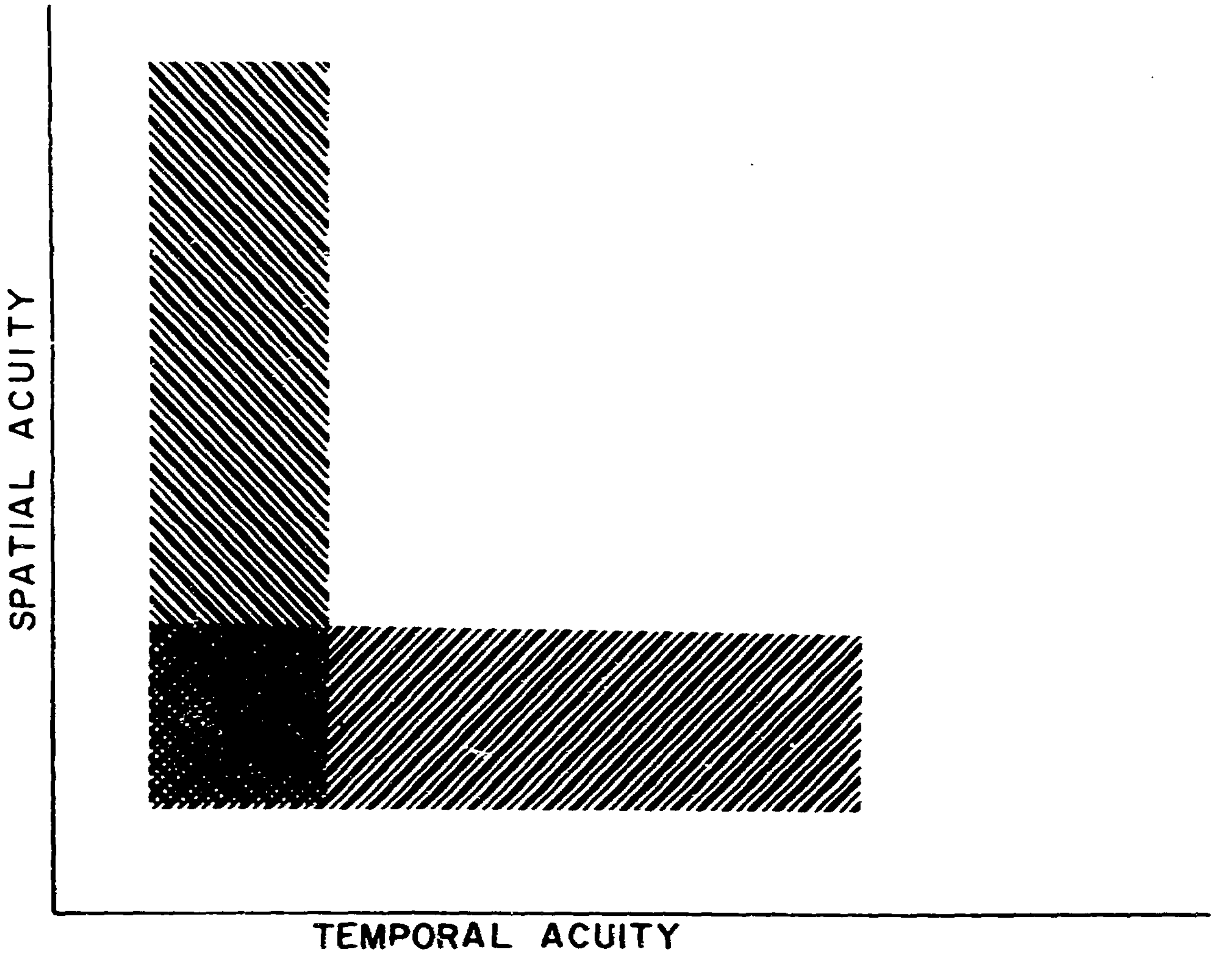


FIGURE 11. A COMPARISON OF TWO SYSTEMS (EYE & EAR) WITH ASSUMED EQUIVALENT CHANNEL CAPACITIES BUT WITH DIFFERENT ACUITIES

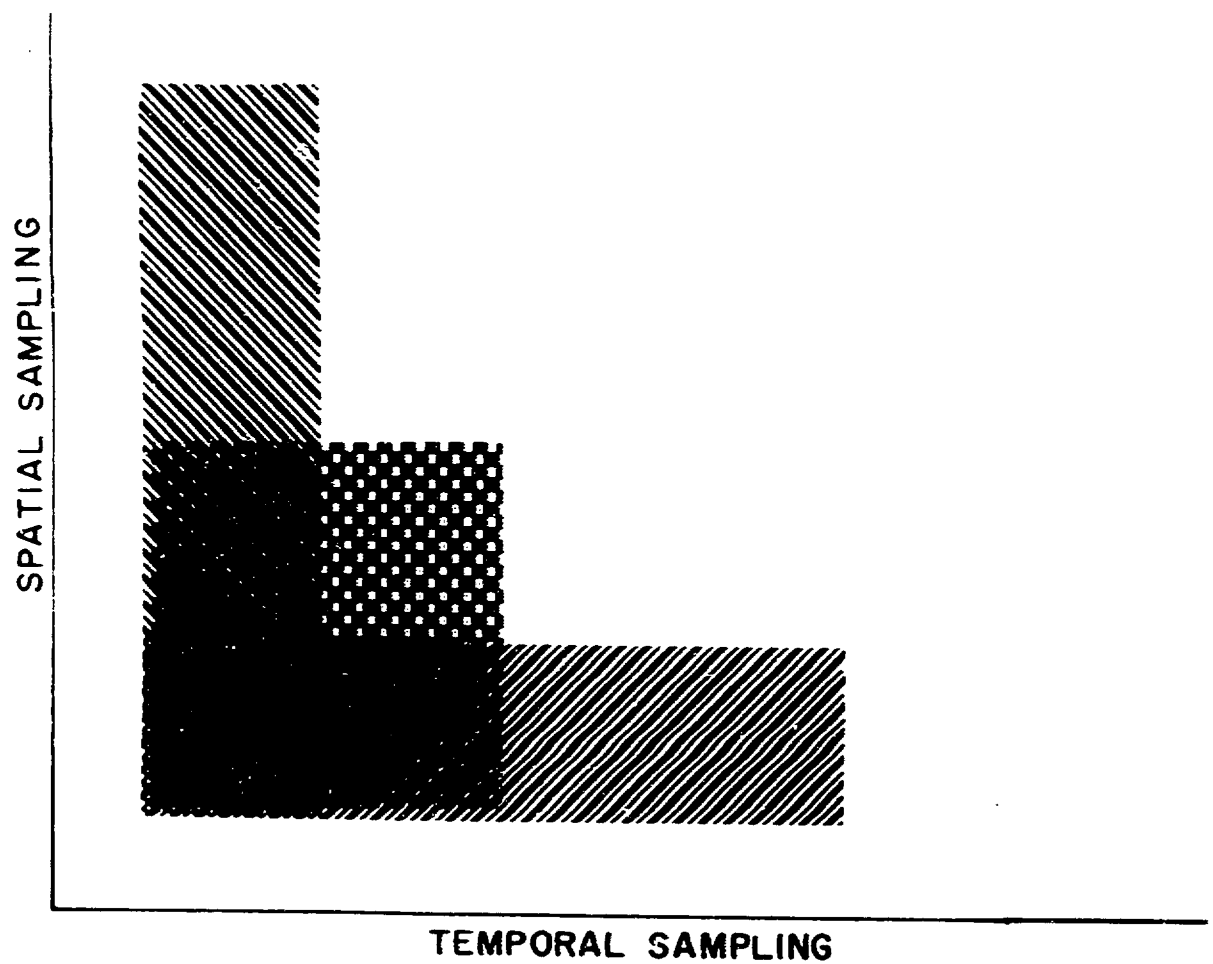


FIGURE 12 THREE PERSONS WITH EQUIVALENT OVERALL CHANNEL CAPACITIES BUT WITH DIFFERENT PREDISPOSITIONS TOWARD THE TYPE OF INFORMATION SELECTED FOR SAMPLING

tend to be vigilant. The person who can monitor many things at once is called a broad band pass ability person, and other things being equal, would tend not to be vigilant to one thing for a long time.

The traits suggested above could be independent of channel capacity, and it is felt that the homogeneity in intelligence of the population in this experiment might control for the influence of this latter variable. The stability of this trait in an individual and the susceptibility of the trait to modification from interest, motivation, and other variables will be discussed later.

The concept which should be tested is band pass ability, i.e., the ability to monitor well many things at once, as contrasted with the ability to be vigilant. The data from the present experiment do not permit an adequate test of this notion, since the two channel vigilance task may not be considered "many" things. However, for purposes of hypothesis gathering, it was decided to examine this relationship in the present data, and if warranted, predict the outcome in another study. To this end, two scores were calculated:

1. Band pass ability: Operationally defined for the purpose as that score obtained by an individual on the five minutes of the two channel test early[15] in the session when the group's performance was best.

2. Vigilance decrement: Operationally defined as the proportion of the decrement and calculated by the equation $\frac{\text{early-late}}{\text{early}}$, where early equals a person's band pass ability score as above, and late equals a person's score

---

[15] "Early" in the session was considered the first half, and "late" the second half.

for the five minutes late in the session when the group's performance was poorest. This score was calculated instead of slope since slope could be expected to be negatively correlated with the initial value (it was), and since high scores, if they change, tend to go down and low scores, if they change, tend to go up ("initial values effect")(Wilder, 1950, 1962)

Band pass ability and vigilance decrement scores were calculated for the two groups of subjects who received the two channel monitoring task, and these two groups were combined. The obtained correlation between band pass ability and vigilance decrement ($r = .185$, $N = 101$) was not significant at a statistically acceptable level by two tailed test (e.g., $P > .05$) for hypothesis testing. However, the correlation was in the predicted direction and of sufficient magnitude ($P = .06$) for hypothesis gathering to provide suggestive support for the band pass ability notion and to warrant further study. It was felt t... a more complex task (e.g., one with more channels) should be studied in order to determine whether the ability to do a complicated multi-channel test would be correlated with proportion of the decrement on that task. Additionally, a simple version of the task should also be studied for comparison.

Individual differences and nystagmus habituation. The present study reported few individual differences of any consequence which predicted nystagmus habituation; however, a paper by Mangan & O'Gorman (1969) is relevant. These authors studied individual differences in the amplitude (initial value) and habituation (time to zero response) of an orienting response (GSR to a 380 Hz tone, at 57 db). Using the Eysenck Personality Inventory (Form B),

they preselected persons with scores on both extraversion and neuroticism which were more than one standard deviation above or below the class mean[16] for the first part of their study.

Their finding, interpreted largely in connection with the work of Sokolov & Eysenck (cited in Mangan & O'Gorman, 1966), was that extraversion and neuroticism are related in different ways to amplitude and habituation of the orienting response: (a) Extreme (high) neuroticism scores were predictive of large orienting responses and (b) a concordance within a person of either high or low personality (neuroticism and extraversion) scores would result in fast habituation and a disconcordance the converse.

These findings were partly replicated (Mangan & O'Gorman, 1966) in a second part of their study, and it was assumed by the authors that "... low-anxious extraverts [High E, Low N] and high-anxious introverts [Low E, High N] display greater dynamism of introversion than the other two groups [High N, High E plus Low N, Low E] " (p. 279); thus these persons habituate more rapidly, as measured by the disappearance of the GSR to a tone.

It is felt that vestibular nystagmus can be considered a modality specific orienting response, and as such, the data from the present study could be cast in a form similar to those of Mangan & O'Gorman (1966) in order to determine the generality of their findings to another stimulus condition. To this end,

---

[16] Their population values are: $M_{EXTRA} = 12.12$; $SD_E = 3.91$, and $M_{NEURO} = 7.76$; $SD_N = 4.44$. The authors do not report their original population size, but most likely mean differences exist between the reference sample in the present study (Table 2) and theirs.

nystagmus scores early in a subject's exposure were considered equivalent to the amplitude of an orienting response, and the proportion of the decrement in nystagmus over the period of sinusoidal oscillation was considered nystagmus habituation for the two groups who were oscillated. Concordance in our sample was said to exist if both neuroticism and extraversion scores were above or below the mean for our sample. This differed from the procedures of Mangan & O'Gorman in two ways: (a) Our mean extraversion and neuroticism scores were higher and lower, respectively, than theirs, and (b) they used only subjects whose scores were extreme (more than one standard deviation). Because both of the above restrict the range in our sample, it is felt that our test of their results would tend to be a more conservative test of the hypotheses.

The initial amplitude and proportion of the decrement scores for each of our two nystagmus groups (groups I and II, Experiment I) were converted to standard scores, and the data from the two groups were combined and then correlated with personality scores in the following way: (a) Neuroticism vs. amplitude of the orienting response, and (b) concordance of neuroticism and extraversion vs. habituation of nystagmus.

The correlation between neuroticism and initial value ($r = .10$) was not significant ($P = .32$), but was in the predicted direction. The correlation between concordance of extraversion and neuroticism with habituation ($r = -.25$) was significant ($P = .01$), supporting the hypothesis of Mangan & O'Gorman (1966) that habituation is slower in persons in whom extraversion and neuroticism scores are not correlated, versus those in whom scores are concordant

(i.e., high N and high E, as well as low E and low N).

Experiment II

Individual Differences in Vigilance Tasks of Differing Complexity

<u>Introduction</u>

In Experiment I, Part 1, the two-channel version of our vigilance task was administered to 100 subjects, half of whom were tested during vestibular stimulation and while nystagmus was recorded and half were controls. In this study, habituation to vestibular stimulation and vigilance decrements covaried ($r = .93$), even when "time" effects were partialled out ($r = .708$). Mean differences in vigilance performance were not obtained between the groups who did or did not receive vestibular stimulation.

In Experiment I, Part 2, personality and exposure history scores were studied in relation to performance with the following results: (a) No clear cut relationships between subject variables (e.g., hours sleep) and performance were found, (b) the positive relationship between introversion scores and vigilance performance found by others (Bakan, 1963; Bakan & Toth, 1963, Broadbent, 1958; Buckner, 1963) was not obtained, (c) a person's "ability" to perform this vigilance task (defined as his score on five minutes of the task early in the session and when the group's performance was highest) and the proportion of his decrement (defined as $\frac{E-L}{E}$ where E = the ability scores above and L = his score for five minutes late in the session when the groups' performance was lowest) tended to be negatively correlated ($r = -.185$), but were not significant ($P = .06$) by two-tailed tests. This latter result is in conflict with the results obtained by Mackworth, who found that subjects who detected more signals early in the session tended to produce less decrement later (cited in

Broadbent, 1958, p. 143).

The task in Experiment I differs from most other vigilance tasks where individual correlates of performance have been found. In our task (e.g., two-channel auditory monitoring), the subject monitored signals of two different tonal qualities and he performed more complicated mental work than merely detection of tnese signals. On the three-channel auditory version of our task (Kennedy, 1971), almost no subject is able to obtain 100% correct for any five-minute time period in a 60-minute session. (Channel as used here refers to separate discriminable tones rather than different sensory input systems (e.g., vision, audition, etc.). When one serves as a subject on our three-channel task, he has the impression he has three separate bins or registers which are continually changing in state, and which are continually cleared or emptied and then filled again. Most persons feel overloaded as they do this work. Performance on three-channel visual (light) monitoring is about equal to two-channel auditory performance (Kennedy, 1971). It was hypothesized that the complexity of our test might be the reason for the difference between our results and those of Mackworth, and it was felt that our three-channel test would increase this difference, while the one-channel performances might be more like those of Mackworth. Further, perhaps study of a simpler version and a more complicated version of our task would produce an interaction between introversion scores and performance. Specifically, it was felt that introverts would perform better on the simpler task and less well on the complex task.

To test these hypotheses, to extend our experience with this vigilance task, and to examine subject and other personality variables, it was decided to expose a large population to the one and three-channel auditory version of this task.

Apparatus and Procedure

All subjects in this experiment heard the same auditory signals for a 60-minute session. The signals were three tones recorded on a magnetic tape as described in Experiment I.

The subjects for the present experiment (N = 206) were student officer, Naval aviation personnel drawn from the same population as described in Experiment I. Testing was accomplished during their first week in the Navy because this would obviate communication about the test between persons who had already taken it and those who had not. Additionally, past experience suggested that at this time in their training, these men are highly motivated to be cooperative in experiments.

The task for all subjects was essentially similar: The subjects were seated in a testing room in groups of 8 - 12. All were given response keys and instructed to listen for a high, a middle, and a low tone. Their task during this ten-minute practice session was to count the low tone's occurrences and when it had sounded four times, they were to "...push a key and begin counting to four again; repeat until told to stop". They were told to ignore the high and middle tone. After the practice session[17] the subjects were randomly assigned to one of two groups. The experimental conditions for the two different groups were:

One-channel task: These subjects (N = 124) were instructed that they were

[17] The previous study (Kennedy, 1971) suggested that a ten-minute practice session was sufficient to remove the main effects of learning from subsequent sessions.

to monitor the low tone as they did in practice (count to four repeatedly, etc.) for a longer (than they did in practice), but unspecified period of time.

Three-channel task: These subjects (N = 82) were instructed to monitor the low tone as in practice and also to simultaneously, but independently, monitor the middle and high tones in the same way.

Prior to the practice session, all subjects filled out the pre-experimentation interview form (Appendix D). In addition, scores of extraversion, neuroticism and field independence were obtained (Appendix A).

Percent correct scores were obtained for each subject for each of 12 five-minute segments in his 60-minute session. Percent correct was used because it permitted a direct comparison of performances of the one and three-channel tasks, and percent correct had been shown to have the highest intercorrelation of several apparently valid methods of scoring (Kennedy, 1971).

In our study, vigilance performance was measured by computing slope ("b" in the formula $Y = a + b X$) and using it as a score. The "proportion of the decrement" was calculated also by $\frac{E-L}{E}$ where E = performance early in the session, and L = performance late in the session. Early performance was defined as 0 - 5 or 5 - 10 minute[18] segment scores. Late performance was defined as the 55-60 minute segment. It was felt that early performance would provide an index of the person's ability on this task, but that the proportion of the decrement would indicate sustained vigilance on this task. Pearson

[18] Whichever was higher for the group.

product-moment correlation coefficients were used to describe the relationships between individual differences in vigilance performance and the various subject variables.

Results

Figure 13 shows the mean percent correct performance in different time segments in the 60-minute session for the two experimental groups. The two-channel data (50-minute sessions) from Experiment I, where vestibular stimulation was used, are included for comparison. As expected, one-channel monitoring is superior to three-channel performance, an advantage that was significant ($P < .01$). The absolute decrement is also significantly greater in the one-channel group ($P < .01$). The relative decrements[19] are about the same for one, two, and three-channel monitoring, about 15-20%.

A correlation matrix is presented in Table 6 and contains relationships between the vigilance task, personality, and questionnaire variables. Personality and history mean scores were not significantly different from those reported in Table 1, and are not reported.

It appears that early (or ability) scores on the one-channel test (variable 1-VB-1) are correlated with field independence (VB-5) number of hours sleep (VB-10), and the subject's estimate of whether the number of hours was sufficient (VB-11). The session mean is also related to sleep. Other than these relationships, performance on the vigilance test does not appear to be predicted by interview or personality.

Of the relationships of the performance test measures alone, ability (VB-1) is correlated with mean performance (BV-2) and with slope (VB-3)

---

[19] i. e., if regression projections are made for 50-60 minute performances in the case of two-channel testing or if all decrements are calculated at 40-50 minutes where data is available for all four groups.

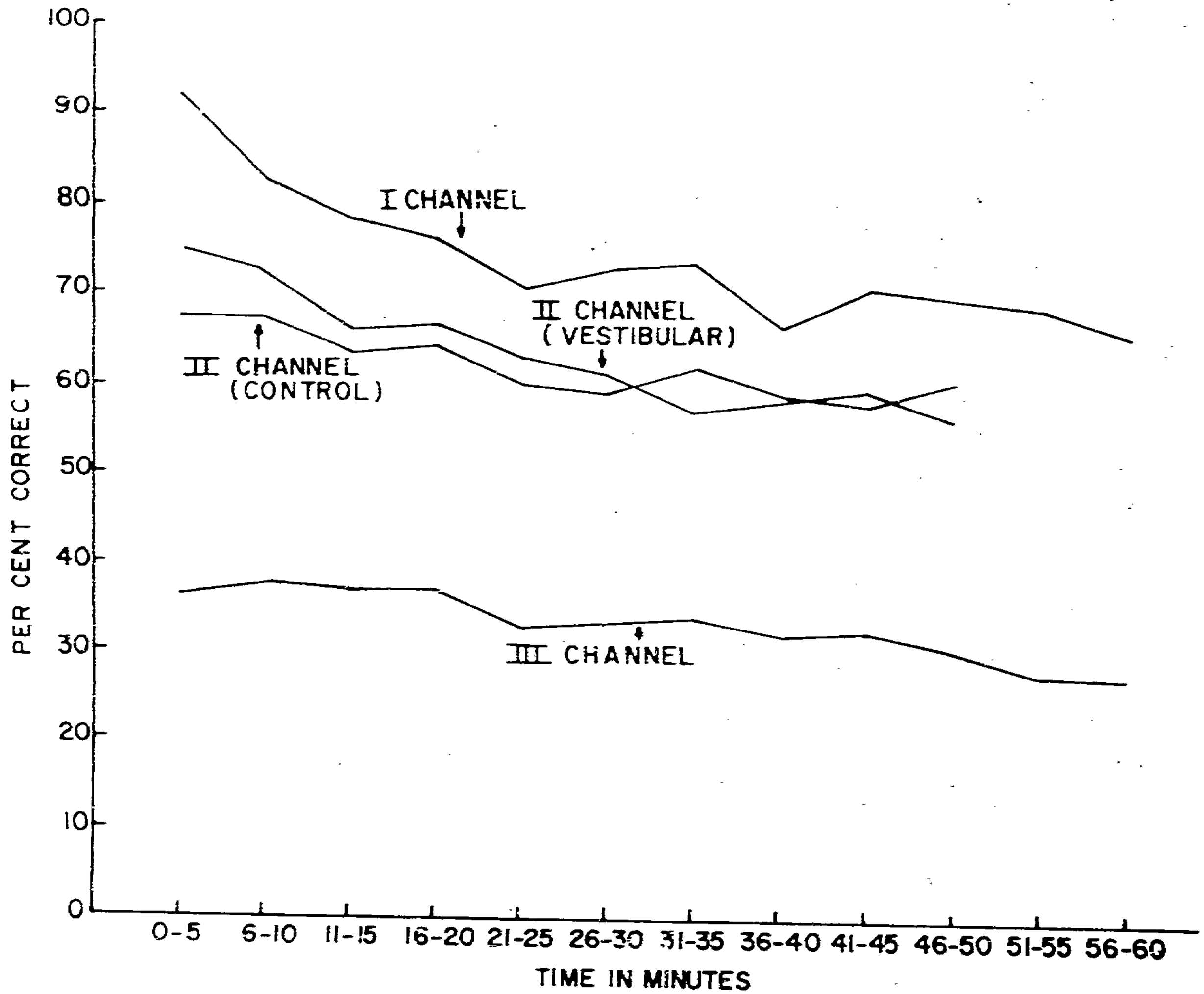


FIGURE 13 MEAN PERCENT CORRECT ON AN AUDITORY VIGILANCE TASK FOR FOUR GROUPS

TABLE 6

Correlation Matrix of Experimental Variables for One-Channel Vigilance Group

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Early Score		.61	-.25	.14	.20	.07	-.11	.11	.09	.21	.20	.05
2. Mean Score			.28	-.18	.13	.01	-.15	.01	.11	.17	.18	.05
3. Vigilance Slope				-.56	-.04	.00	-.02	-.13	.09	.02	-.04	-.01
4. Proportion Decrement					-.13	.14	.06	.01	-.09	.02	.11	.06
5. Field Independence						-.04	-.01	.02	.09	.17	-.04	.03
6. Extraversion							.47	.11	-.16	-.16	-.07	.21
7. Neuroticism								.01	-.02	-.18	-.14	.10
8. Illness									.15	.28	.18	-.08
9. Fitness										.16	.19	-.18
10. Hours Sleep											.63	-.08
11. Sufficient												-.01
12. Concern												

Where $N = 124 - r_{.10} = .15$; $r_{.05} = .18$; $r_{.01} = .23$; $r_{.001} = .30$

Two-tailed significance values of r for $P < .10$.

the latter probably the result of the initial values effect (Wilder, 1950, 1962). While ability is not related to decrement (VB-4), the mean is. The two indicants of vigilance (VB-3 and 4) are correlated with each other. Table 7 contains the same variables as Table 6, but for the three-channel monitoring task. Field independence (VB-5) is again related to mean performance (VB-2) and is in the same direction for the other ability measure (VB-1) as in Table 6, where significance was obtained. Estimated fitness (VB-9) is related to decrement (VB-4), but other personality and questionnaire scores were not related to vigilance. It should be noted that ability (VB-1) on this complex vigilance task was related to decrement (VB-4), whereas it had not been for one-channel monitoring (Table 6). This relationship, along with the result from Experiment II, is summarized in Table 8. The interrelationships of the other vigilance variables are essentially the same as for one-channel monitoring.

The percent of the subjects claiming that they were fit, had no drugs, etc., was essentially the same as reported in Experiment II; generally over 90% responded in the same way. This low variability suggests that the obtained correlations between vigilance performance and questionnaire items (Tables 6 and 7) should be interpreted with caution. They are reported here because they were calculated[20], and because the sample sizes were somewhat larger

[20]The descriptive statistics for Experiment I and II were all calculated at about the same time and so the correlation matrices were available when the low mean variability in pre-experimentation interview response was found to exist.

TABLE 7

Correlation Matrix of Experimental Variables for Three-Channel Vigilance Group

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Early Score		.75	-.26	.22	.17	.10	.00	-.02	-.06	-.07	-.09	.01
2. Mean Score			.19	-.11	.29	.11	-.08	.01	-.05	.11	.05	-.06
3. Vigilance Slope				-.03	.16	.00	.03	.03	.03	.14	.13	-.06
4. Proportion Decrement					-.12	-.10	.08	-.04	.30	-.05	.04	-.07
5. Field Independence						.15	-.06	.02	.06	.19	.25	.02
6. Extraversion							.32	-.05	-.02	.15	.17	.08
7. Neuroticism								.18	-.06	.03	.14	.10
8. Illness									.35	.08	.21	.21
9. Fitness										.12	.19	.28
10. Hours Sleep											.62	.03
11. Sufficient												-.03
12. Concern												

Where $N = 82 - r_{.10} = .18^{*}$; $r_{.05} = .22$; $r_{.01} = .29$; $r_{.001} = .36$

*Two-tailed significance values of r for $P < .10$.

TABLE 8

Correlations Between Early Score and Proportion of the Decrement for One, Two and Three-Channel Vigilance Groups

	r	P Value	N
One Channel	.14	>.10	124
Two-Channel	.19	<.06	109
Three-Channel	.22	<.05	82

than those in Experiment I.

Support for the finding (Bakan, 1963; Bakan & Toth, 1963; Broadbent, 1958; Buckner, 1963) that introverts are more vigilant than extraverts was not obtained, although the correlation between vigilance and extraversion obtained in one-channel monitoring was in the predicted direction ($r = .14$) and was significantly different ($P < .01$) from that obtained for three-channel ($r = -.10$) monitoring.

Discussion and Conclusions

It was shown that it is possible to obtain a time-course score for a given individual and to relate this score (slope or proportion of decrement) to certain subject variables which logically should determine vigilance behavior (e.g., sleep and fitness), and to some extent to personality, viz., field independence and extraversion.

The large number of signals presented in our vigilance tests allow us to calculate a number of scores for each person, and therefore a fine-grained analysis of performance over time can be calculated. In most other vigilance studies (e.g., see Buckner & McGrath, 1963), so few signals are used that group comparisons must usually be made in order to study the effects of various experimental treatments, and the investigation of individual differences is only possible by using extreme groups.

While the significant subject variables that were found in our study require cross validation, the present study reports on a vigilance task which can be scored in ways which avoid some of the shortcomings of vigilance tasks with few signals. For example, the original studies of vigilance were designed to investigate performance during long term exposure to infrequent, weak signals (Broadbent, 1964). Many of these studies merely compare the number of detections during the last half hour of a watch with the first half hour. However, when there are fewer than ten signals (chances) in an entire (e.g., 90 minutes) watch, it is difficult to plot a person's "vigilance" over the watch, therefore pooling is usually done over large portions of the watch and often over subjects,

as well.

It is felt that proportion of the decrement and slope over time are better definitions of the construct "vigilance" and they are less influenced by an ability to perform a particular kind of work, than is the average number of hits in the last third of a watch.

It should be noted that the similarities and differences in the correlations between performances on the one and three-channel tasks suggest that while there are common elements in vigilance, there are also probably task-specific factors. Two of the results mentioned above are important in this regard: (a) A good ability score on three-channel auditory monitoring was positively correlated with a subsequent decrement. Whereas in Experiment I, Part 2, on two-channel monitoring, this relation was barely insignificant, and again in the present study on one-channel monitoring, ability was less related to the decrement[21], and (b) significantly different relationships between high scores on an extraversion test and performance on three-channel vs. one-channel monitoring were obtained ($P < .01$), although neither relationship alone was significantly different from zero.

These two results appear to conflict with findings on the individual differences in vigilance performance reported elsewhere (Bakan, 1963; Bakan et al,

[21]The inability to replicate Mackworth's (cited in Broadbent, 1958) finding on our one-channel test may mean that an even simpler version of our test might be required to obtain the result that a high proportion of detections early in a session is predictive of better vigilance. Unpublished observations indicate this to be so when the subject monitors two-channel signals, but presses for each occurrence, rather than counting ($P < .001$) (see Appendix C).

1963; Broadbent, 1958; Buckner, 1963), and a rationale is offered herewith in an effort to incorporate both results. It is felt that these individual differences represent measurable factors in individual styles of information processing.

It is suggested that there are two main kinds of people or styles with respect to information processing. Some people are multi-channel or broad band-pass people, and others have narrow band-pass filters. When channel capacity (as defined previously) is constant, the latter make up for their lack of ability to attend simultaneously to many things by being able to sustain attention to one class of events for a long time, and are called long-term monitors. A long-term monitoring ability would be positively correlated with narrow band-pass ability. Also, broad band-pass ability would be correlated with short term monitoring. Therefore, it is felt that persons with high broad band-pass abilities tend not to be vigilant. (One would expect that they would also be more extraverted, although no significant relationship was found in Table 7 (r = .10).

While the data in the present paper only suggest the notion described above and should be cross-validated[22], the framework offered here provides a number of interesting and potentially useful lines of investigation, along with testable hypotheses. For example, does a person's band-pass ability (broad or narrow) as determined by this test correlate across sensory inputs?

---

[22]A form of cross-validation with positive results is reported in Appendix C.

Tasks? Is it a unitary trait? Can a broad band-pass person function well in a long term monitoring situation with training, motivation, etc.? What is the influence of interest? Stress? What is the incidence of broad band-pass/short term monitoring ability (vs. the converse) in the population? Can jobs be classified and people better allocated to fill them on the basis of the above relationships? Specifically, many occupations require long term monitoring with relatively single channel work early in a person's career, but later in a career the work becomes more multi-channel, often with shorter term monitoring required (e.g., air traffic controlling). Assuming the traits "broad band-pass" and "long term monitoring" are identifiable and negatively correlated, are they modifiable? Does the ratio of the former to the latter increase with age?

References

Antrobus, J. S. & Antrobus, J. S. Rapid eye movements and rapid eye movement periods. Psychophysiology, 1969, 6, 45-48.

Azzena, G. B., Desole, C., & Palmieri, G. Cerebellar projections of the masticatory and extraocular muscle proprioception. Experimental Neurology, 1970, 27, 151-161.

Bach y Rita, P., & Collins, C. (Eds.) Control of eye movements. New York: Academic Press, 1971.

Bakan, P. Time-of-day preference, vigilance and extraversion-introversion. In D. N. Buckner & J. J. McGrath (Eds.) Vigilance: A symposium. New York: McGraw-Hill, 1963, 114-117.

Bakan, F., Belton, J. A., & Toth, J. C. Extraversion-introversion and decrements in an auditory vigilance task. In D. N. Buckner & J. J. McGrath (Eds.) Vigilance: A symposium. New York: McGraw-Hill, 1963, 22-33.

Brictson, C. A., Burger, W. J., & Kennedy, R. S. Predicting the quality of pilot landing performance during night carrier recovery. Aerospace Medicine, 1971, 42, 16-19.

Broadbent, D. A. Perception and communication. New York: Pergammon Press, 1958, Ch. 5 - 7.

Broadbent, D. A. Vigilance. British Medical Bulletin, 1964, 20, 17-20.

Brodal, A., Pompeiano, O., & Walberg, F. The vestibular nuclei and their connections, anatomy and functional correlations. Edinburgh: Oliver & Boyd, 1962.

Brodal, A. Anatomical aspects of functional organization of the vestibular nuclei. Second symposium on the role of the vestibular organs in space exploration. NASA Special Report SP-115, 1966, 119-141.

Buckner, D. N. An individual difference approach to explaining vigilance performance. In D. N. Buckner & J. J. McGrath (Eds.) Vigilance: A symposium. New York: McGraw-Hill, 1963, 171-183.

Buckner, D. N., & McGrath, J. J. Vigilance: A symposium. New York: McGraw-Hill, 1963.

Burnham, C. A. Decrement of the Muller-Lyer illusion with saccadic and tracking eye movements. Perception and Psychophysics, 1968, 3, 424-426.

Buros, O. K. (Ed.) The sixth mental measurements yearbook. Highland Park, N.J.: Gryphen Press, 1965.

Byford, G. Eye movements and the optogyral illusion. Aerospace Medicine, 1963, 34, 119-123.

Camis, M. Physiology of the vestibular apparatus. Trans. by R. S. Creed. Oxford: Clarendon Press, 1930.

Cohen, B., Feldman, M., & Diamond, S. P. Effects of eye movement, brain-stem stimulation, and alertness on transmission through lateral geniculate body of monkey. Journal of Neurophysiology, 1969, 32, 583-594.

Cohen, B., Suzuki, J., Shanzer, S., & Bender, M. B. Semi-circular canal control of eye movements. In M. Bender (Ed.) The oculomotor system. New York: Harper & Row, 1964, 163-172.

Cohen, J. Multiple regression as a general data analytic system. Psychological Bulletin, 1968, 70, 426-443.

Collins, W. E., Crampton, W. E., & Posner, J. B. Effects of mental activity on vestibular nystagmus and the electroencephalogram. Nature, 1961, 190, 194-195.

Collins, W. E., & Posner, J. B. Electroencephalogram alpha activity during mild vestibular stimulation. Nature, 1963, 199, 933-934.

Crawford, W. A. The perception of moving objects: II. Eye movements. Farnborough, England: Institute of Aviation Medicine, RAF, FPRC/ Memo 150b, 1960 (a).

Crawford, W. A. The perception of moving objects: III. The coordination of eye and head movements. Farnborough, England: Institute of Aviation Medicine, RAF, FPRC/Memo 150c, 1960 (b).

Crawford, W. A. The perception of moving objects: V. The moment of perception. Farnborough, England: Institute of Aviation Medicine, RAF, FPRC/Memo 150e, 1960 (c).

Crawford, W. A. The perception of moving objects: VII. Some observations on the presence of proprioceptive information from extraocular eye muscles. Farnborough, England: Institute of Aviation Medicine, RAF, FPRC/Memo 150f, 1960 (d).

Cronbach, L. J. The two disciplines of scientific psychology. American Psychologist, 1957, 12, 671-684.

Daniel, R. S. Electroencephalographic pattern quantification and the arousal continuum. Psychophysiology, 1965, 2 (2), 146-160.

Daroff, R. B. & Hoyt, W. F. Supranuclear disorders of ocular control system in man: Clinical, anatomical and physiological correlations. Control of eye movements. In P. Bach y Rita & C. Collins (Eds.) Control of eye movements. New York: Academic Press, 1971.

Davies, D. R. & Tune, G. S. Human vigilance performance. London: Staples Press, 1970.

DeFazio, V. J. & Moroney, W. F. Performance characteristics of field dependent and independent individuals on an auditory signal detection task. The Journal of Psychology, 1969, 71, 77-82.

Dodge, R. Visual perception during eye movement. Psychological Review, 1900, 7, 454-465.

Dodge, R. The illusion of clear vision during eye movement. Psychological Bulletin, 1906, 2, 193-199.

Duffy, F. H. & Lombroso, P. Electrophysiological evidence for visual suppression to the onset of a voluntary saccadic eye movement. Nature, 1968, 218, 1074-1075.

Eysenck, H. J. The scientific study of personality. New York: MacMillan, 1952.

Eysenck, H. J. The structure of human personality. New York: Wiley, 1953.

Eysenck, H. J. The dynamics of anxiety and hysteria. New York: Praeger, 1957.

Eysenck, H. J. Experiments in motivation. New York: MacMillan, 1964.

Eysenck, H. J. & Eysenck, S. B. G. Manual for the Eysenck Personality Inventory. San Diego, Calif.: Education & Industrial Testing Service, 1963.

Evans, F. J. Field independence and the Maudsley Personality Inventory. Perceptual and Motor Skills, 1967, 24, 526.

Evans, F. J. Effects of practice on the validity of a group-administered embedded figures test. Acta Psychologica, 1969, 29, 172-180.

Ford, A. & Leonard, J. L. Techniques for recording surface bioelectric currents. San Diego, Calif.: Naval Electronics Lab. Report No. 839, 1958.

Franks, C. M. Differences determinees par la personnalite dans la perception visuelle de la verticalite. Revue de Psychologie Appliquee, 1956, 6(4), 235-246. (Cited in Evans, F. J., Perceptual Motor Skills, 1967.)

French, J. W., Ekstrom, R. B., & Leighton, A. P. Manual for kit of reference tests for cognitive factors. Princeton, N. J.: Educational Testing Service, 1962.

Gaardner, K. Fine eye movements during inattention. Nature, 1966, 209, 83-84.

Gernandt, B. Vestibular mechanisms. In Field & Magoun (Eds.) Handbook of physiology. Vol. I. Neurophysiology. Phila: Williams & Wilkins, 1959, 549-564.

Gonshor, A. & Melvill-Jones, G. Investigation of habituation to rotational stimulation within the range of natural movement. Presented at 49th Annual Meeting of the Aerospace Medical Association, San Francisco, 1969.

Goodson, J. E. Optokinetic response in the pigeon. Unpublished doctoral dissertation, Geo. Washington University, 1969.

Graybiel, A. & Hupp, D. The oculogyral illusion: A form of apparent movement which may be observed following stimulation of the semicircular canals. Journal of Aviation Medicine, 1946, 3, 1-12.

Gross, E. G., Vaughn, H. G., Jr., & Valenstein, E. Inhibition of visual evoked responses to patterned stimuli during voluntary eye movements. Electroencephalography and Clinical Neurophysiology, 1967, 22, 204-209.

Guedry, F. E. Psychophysiological studies of vestibular function. In W. D. Neff (Ed.) Contributions to sensory physiology, Vol. 1. New York: Academic Press, 1965. Pp. 63-135.

Guedry, F. E. Relations between vestibular nystagmus and visual performance. Aerospace Medicine, 1968, 39, 570-579.

Haltrecht, E. J. & McCormack, P. D. Monitoring eye movements of slow and fast learners. Psychonomic Science, 1966, 6(10), 461-462.

Hardacre, L. E. & Kennedy, R. S. Some issues in the development of a motion sickness questionnaire for flight students. Aerospace Medicine, 1963, 34, 401-402.

Haronian, F. & Sugerman, A. A. Field independence and resistance to reversal of perspective. Perceptual and Motor Skills, 1966, 22, 543-546.

Haronian, F. & Sugerman, A. A. The application of Werner's dimension of fixity-versus-mobility to Witkin's concept of field independence. In press.

Harris, J. D. Habituatory response decrement in the intact organism. Psychological Bulletin, 1943, 40, 385-422.

Helmholtz, H. von. Helmholtz' treatise on physiological optics, English trans. by Southall, J. P. C. Menasha, Wisc.: Optical Society of America, 1925, 3.

Hixson, W. C. & Niven, J. I. A bioinstrumentation control center for the human disorientation device. Pensacola, Fla., U. S. Naval School of Aviation Medicine. Project MR005.13-6001 Subtask 1, Report No. 79 and NASA Order No. R-1, 1963, 22 pp.

Immergluck, L. Figural after-effects, rate of "figure-ground" reversal, and field independence. Psychonomic Science, 1966, 4, 45-46 (a).

Immergluck, L. Visual figural after-effects and field dependence. Psychonomic Science, 1966, 4, 219-220. (b)

Jackson, D. N., Messick, S., & Myers, C. T. Evaluation of group and individual forms of embedded-figures measures of field independence. Educational and Psychological Measurement, 1964, 24, 177-192.

Jacobson, E. Electrical measurements of neuromuscular states during mental activities. American Journal of Physiology, 1930, 95, 694-702.

Johnson, L. C. A psychophysiology for all states. Psychophysiology, 1970, 6 (5), 501-516.

Jones, G. M. Discussion of vestibular stabilization of eye movements. In P. Bach y Rita & C. Collins (Eds.) Control of eye movements. New York: Academic Press, 1971.

Karp, S. A. Field independence and aging. Research Reports of Sinai Hospital of Baltimore, 1966, 1, 1-9.

Kennedy, R. S. Two procedures for applied and experimental studies of stress. Pensacola, Fla.: Naval Aerospace Medical Institute, 1970, NAMI-1099, 13 pp.

Kennedy, R. S. A comparison of performance on visual and auditory monitoring tasks. Human Factors, 1971, 13, 93-97.

Kirkwood, B. Relationship between the electroencephalogram eye movements and fluctuations of visual perception. Psychonomic Science, 1967, 7, 417-418.

Kottenhoff, H. Situational and personal influences on space perception with experimental spectacles: II Semiprolonged tests with inverting glasses. Acta Psychologica, 1957, 13, 151-161.

Kottenhoff, H. & Lindahl, L. E. H. Visual and emotional factors in motion sickness: Preliminary communication. Perceptual and Motor Skills, 1958, 8, 173-174.

Lubin, A., Johnson, L. C., & Austin, M. T. Discrimination among states of consciousness using EEG spectra. Psychophysiology, 1969, 6(2), 122-132.

Lynn R. Attention, arousal and the orientation reaction. Oxford: Pergammon Press, 1966, 118 pp.

Mackworth, J. F. Vigilance, arousal and habituation. Psychological Review, 1968, 75(4), 308-322.

Mackworth, J. F. Vigilance and habituation. A neuropsychological approach. Baltimore: Penguin Books, 1970.

Mangan, G. L. & O'Gorman, J. G. Initial amplitude and rate of habituation of orienting reaction in relation to extraversion and neuroticism. Journal of Experimental Research in Personality, 1969, 3, 275-282.

Manni, E., Azzena, G. B., Casey, H., & Dow, R. S. Influence of the labyrinth on unitary discharge of the oculomotor nucleus and some adjacent formations. Experimental Neurology, 1965, 12, 9-24.

Manni, E., Azzena, G. B., & Dow, R. S. Convergenze cerebellari e labirintiche sulle strutture nervose mesencefaliche adiacenti al nucleo dell 'oculomotore. Bollettino della Societa' Italiana di Biologica Sperimentale, 1965, 41, 1130-1131.

Manni, E., Bortolami, R., & Desole, C. Peripheral pathway of eye muscle proprioception. Experimental Neurology, 1968, 22, 1-12.

Marg, E. Development of electro-oculography. AMA Archives of Ophthalmology, 1951, 45, 169-185.

Matin, L., & Pearce, D. G. Visual perception of direction for stimuli flashed during voluntary saccadic eye movements. Science, 1965, 148(3676), 1485-1488.

McCabe, B. F. The quick component of nystagmus. The Laryngoscope, 1965, 75(10), 1619-1646.

McNally, W. J., & Stuart, E. A. Physiology of the labyrinth reviewed in relation to seasickness and other forms of motion sickness. War Medicine, 1942, 683-771.

Michael, J. A., & Stark, L. Electrophysiological correlates of saccadic suppression. Experimental Neurology, 1967, 17(2), 233-246.

Morrison, A. R., & Pompeiano, O. Vestibular influences on vegetative functions during the rapid eye movement periods of desynchronized sleep. Experientia, 1965, 21(11), 667-668.

Mulholland, R. T. & Evans, C. R. An unexpected artefact in the human electroencephalogram concerning the alpha rhythm and the orientation of the eyes. Nature, 1965, 207, 36-37.

Mulholland, T., & Evans, C. R. Oculomotor function and the alpha activation cycle. Nature, 1966, 211, 1278-1279.

Murphy, D. E. Sensory deprivation, suggestion, field dependence, and perceptual regression. Journal of Personality and Social Psychology, 1966, 4, 289-294.

Niven, J. I., Hixson, W. C., & Correiâ, M. J. An experimental approach to the dynamics of the vestibular mechanisms. In The Role of the Vestibular Organs in the Exploration of Space. Pensacola, Fla.: U. S. Naval School of Aviation Medicine, NASA SP-77, 1965, 43-56.

Owens, W. A. Toward one discipline of scientific psychology. American Psychologist, 1968, 23(11), 782-785.

Pasik, T., Pasik, P., Bender, M. B. The superior colliculi and eye movements. Archives of Neurology, 1966, 15, 420-436.

Pompeiano, O., & Morrison, A. R. Vestibular influences during sleep. Archives Italienne de Biologie, 1965, 103, 569-595.

Reding, G. R., & Fernandez, C. Effects of vestibular stimulation during sleep. EEG and Clinical Neurology, 1968, 24, 76-79.

Riggs, L. R. Visual effects of minimal eye movements. In Second symposium on physiological psychology. Pensacola, Fla.: School of Aviation Medicine, 1958, 123-136.

Robinson, D. A. The mechanics of human saccadic eye movement. Journal of Physiology, 1964, 174, 246-264.

Robinson, D. A. The oculomotor control system: A review. Trans IEEE, 1968, 56, 1032-1049.

Rossi, A. M., Furhman, A., & Solomon, P. Sensory deprivation; arousal and rapid eye movement correlates of some effects. Perceptual and Motor Skills, 1964, 19, 447-451.

Sala, O. Vestibular efferent system. Acta Oto-Laryngologica, 1964, 59, 329-337.

Sala, O. Efferent vestibular system. Acta Oto-Laryngologica, 1965, Suppl. 197.

Steele, J. R. Discussion to paper by Niven et al. In The role of the vestibular organs in the exploration of space. NASA Special Report #77, 1965, p. 56.

Steinman, R. M., Cunitz, R. J., & Timberlake, G. T. Voluntary control of microsaccades during maintained monocular fixation. Science, 1967, 155(3769), 1577-1579.

Thompson, R. G. & Spencer, W. A. Habituation: A model phenomenon for the study of neuronal substrates of behavior. Psychological Review, 1966, 173, 16-43.

Travis, R. C. & Dodge, R. Experimental analysis of the sensorimotor consequences of passive oscillation, rotary and rectilinear. Psychological Monographs, 1928, 38, 1-96.

Tursky, B. & O'Connell, D. N. A comparison of AC and DC eye movement recording. Psychophysiology, 1966, 3, 157-163.

Volkmann, F. C., Schick, A. M. L., & Riggs, L. A. Time course of visual inhibition during voluntary saccades. Journal of the Optical Society of America, 1968, 58(4), 562-569.

Wasman, M., Morehead, S. D., & Lee, H. Interaction of electro-ocular potentials with the contingent negative variation. Psychophysiology, 1970, 7(1), 103-111.

Weiss, A. D., & Barlow, J. S. Compensatory eye movements in a Barany chair: Effect of visual cues, eye closure, attention, and vestibular disease. Excerpta Medica. International Congress Series No. 193, 4th International Congress of Neurological Surgery, 9th International Congress of Neurology, 1969.

Wendt, G. R. An interpretation of inhibition of conditioned reflexes as competition between reaction systems. Psychological Review, 1936, 43, 258-281. (a)

Wendt, G. R. The form of the vestibular eye movement response in man. Psychological Monographs, 1936, 47, 311-328. (b)

Wendt, G. R. Some characteristics of vestibular eye movements. In Psychophysiological factors in spatial orientation. US ONR Symposium Pensacola, Fla.: USNAS, 1950.

Wendt, G. R. Vestibular functions. In S. S. Stevens (Ed.) Handbook of experimental psychology. New York: Wiley, 1951, 1191-1223.

Wendt, G. R. The nature of adaptation to oscillatory rotation. In The role of the vestibular organs in the exploration of space, NASA Special Report SP-77, 1965, 133-139.

Wendt, G. R. Personal communication, 1967.

Wilder, J. The law of initial values. Psychosomatic Medicine, 1950, 12, 392.

Wilder, J. Basimetric approach (law of initial value) to biological rhythms. Annals New York Academy of Sciences, 1962, 98, 1211-1220.

Witkin, H. A. Perception of body position and of the position of the visual field. Psychological Monographs, 1949, 73(7), 302.

Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. R., & Karp, S. A. Psychological differentiation: Studies of development. New York: Wiley, 1962.

Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Meissner, P. B., & Wapner, S. Personality through perception. New York: Harper, 1954.

Witkin, H. A., Personal communication, 1967.

Wolfe, J. W. Evidence for cerebellar control over habituation of vestibular nystagmus. Unpublished doctoral dissertation, University of Rochester, N. Y., 1966.

Yessenow, M. D. A study of the relationship between nystagmus eye movements and the oculogyral illusion. Unpublished doctoral dissertation, University of Rochester, N.Y., 1969.

Young, L. R. A control model of the vestibular system. Presentation at the International Federation of Automatic Control, Yerivan, Armenia, USSR, 1968.

Young, L. R. Personal communication, 1969.

Yules, R. B., Krebs, C. Q., & Gault, F. P. Reticular formation control of vestibular system. <u>Experimental Neurology</u>, 1966, <u>16</u>, 349-358.

Zuber, B. L., & Stark, L. Saccadic suppression: Elevation of visual threshold associated with saccadic eye movements. <u>Experimental Neurology</u>, 1966, <u>16</u>(1), 65-79.

Appendix A

Intercorrelations, Norms, and Validities of Extraversion, Neuroticism and Field Independence Scores for Student Naval Aviation Personnel

Introduction

The literature reporting a comparison of field independence (Witkin, 1949; Witkin, Dyk, Faterson, Goodenough & Karp, 1962) and extraversion (Eysenck, 1952, 1953, 1957, 1963, 1964) is sparse. In one study (Evans, 1967), a negative relationship between field independence and extraversion was reported for a small (N = 59) sample. One reason for the meager literature may be that while paper and pencil tests of extraversion are available, field independence (Witkin, 1949, 1950) is frequently measured individually by "situation" tests (Witkin, Lewis, Hertzman, Machover, Meissner & Wagner, 1954, p. xxi). The recent (French, Ekstrom & Leighton, 1963; Jackson, Messick & Meyers, 1964) development of a group administered paper and pencil test of field independence has afforded the opportunity to (a) establish norms and reliabilities for a large population of Naval personnel for such tests, and (b) compare the relationships of personality scores on these tests. In addition, while some personality variables would appear to be related to better performance in aviation training[1], most studies of this relationship have not been particularly successful (Fleischman, Ambler, Peterson & Lane, 1966; Peterson, Lane & Kennedy, 1965; Shoenberger, 1963; Voas, Bair & Ambler, 1957). One exception to this generality is a study by Green (1963), where a small group of persons (N = 33) who voluntarily withdrew from training, produced higher mean neuroticism scores than did those (N = 47) still in training one hear hence.

The secondary purpose of the present study was to replicate the study of

[1]For example, Cullen, Harper & Kidera (1969) have shown commercial airline pilots to be relatively more field independent than flight engineers.

Green (1963) in a larger population and to extend the investigation to include other kinds of failure (e.g., academic and flying), as well as other kinds of aviation training (e.g., navigator). It was hypothesized that high scores on tests of field independence and extraversion and low scores on neuroticism would be related to success in aviation training.

Method

The Group Embedded Figures Test (GEFT) (French et al., 1963; Jackson et al., 1964) and the Eysenck Personality Inventory - Form B (EPI-B) (Eysenck & Eysenck, 1963) were administered to over 4,000 subjects. Two-thirds of the subjects also received the Eysenck Personality Inventory - Form A (EPI-A) (Eysenck & Eysenck, 1963), and one-third also received the Maudsley Personality Inventory (MPI) (Eysenck, 1959). The subjects were all student Naval aviation personnel, about two-thirds of whom were student pilots, called Naval Aviation Officer Candidates (AOC's); the rest were non-pilot Naval Flight Officer Candidates (NFO's) (e.g., radar intercept operators, navigators, etc.). A high score on the GEFT served as the measure of field independence. Extraversion/neuroticism was assessed by scores on the MPI, EPI-A, and EPI-B. The EPI's also have a "lie" score adapted from the MMPI lie scale (Buros, 1965, item 93).

The students were tested early in their training; the GEFT and one extraversion/neuroticism test (either EPI-A or the MPI) were administered during the students' first week in the Navy, and the EPI-B was given in the ninth week. Virtually 100% of the student input to aviation training between October, 1967, and October, 1968, was tested. The MPI and EPI-A were both interdigitated throughout the year.

All experimental variables were entered into a correlation matrix, along with the existing Aviation Selection Tests (Ambler, 1968). The latter are paper and pencil instruments, and include a test of numerical and verbal ability (Aviation Qualification Test - AQT), mechanical aptitude (Mechanical

Comprehension Test - MCT), spatial orientation (Spatial Apperception Test - SAT), and a demographic questionnaire (Biographical Inventory). Scores on these tests are used primarily to select (screen) applicants for Naval aviation training. In addition, certain combinations of higher scores on these tests are also indicative of higher likelihoods of success, once a person is <u>in</u> training (Ambler, 1968; Berkshire, Wherry, & Shoenberger, 1965). For the most part, these tests were standardized and validated on an AOC (vice NFO) population.

The Aviation Selection Test scores and those of the personality tests were compared with the dichotomous criterion of pass/separate. A person who "passed" was one who graduated, and received his wings; "separate" was used for persons who did not complete training for any reason. The training program requires between 12 - 18 months, depending on the type of training (pilot, navigator, etc.).

The Wherry-Doolittle method of multiple regression was employed to determine whether scores on the personality tests were predictive of success in training, and also the extent to which these tests added unique variance not presently predicted by the Aviation Selection Tests (Ambler, 1968; Berkshire et al., 1965; Fleischman et al., 1966; Peterson & Lane, 1966).

The population (N = > 4,000) was divided evenly into an empirical evaluation group, and a cross validation group. Each of these groups was subdivided into an AOC group and an NFO group.

Results

Tables 9 and 10 contain descriptive statistics for the AOC's and NFO's, respectively. It may be seen that higher scores (more field independent) are obtained by student pilots (AOC's) than by non-pilot personnel (NFO's) ($P < .05$). Extraversion scores for both groups of subjects (AOC and NFO) are higher than published norms on all three forms of these tests (Eysenck, 1959; Eysenck & Eysenck, 1964), AOC's scoring at about the 60th percentile, and NFO's about the 55th percentile. The latter differences between AOC's and NFO's was significant ($P < .05$). Neuroticism mean scores were lower than published norms for both groups, with AOC's (20th percentile) being significantly ($P < .05$) lower than NFO's (25th percentile). The lie scores for both groups were at about the 59th percentile, but significantly lower scores were obtained by NFO's ($P < .05$).

There were mean differences between AOC's and NFO's on the Aviation Selection Test variables, and it should be recalled that these tests were originally constructed as tests for student pilots (Ambler, 1968).

Table 11 contains intercorrelations of personality tests for the two groups of aviation personnel (AOC and NFO) who received the EPI-A and the two who received the MPI. In pilots (AOC's), field independence is negatively correlated with extraversion, but this relationship was not found for the NFO groups. All other relationships were essentially similar in the two groups, namely (a) extraversion was significantly negatively correlated with neuroticism, (b) reliabilities on two tests each of neuroticism and extraversion were only moderate ($r \cong .63$), (c) reliabilities of lie scores on two tests were low ($r \cong .33$), (d) field independence scores were essentially uncorrelated with other variables, and (e) lie

TABLE 9

Descriptive Statistics for Experimental Variables for Student Pilots (AOC's)

Variable	N	Mean	Standard Deviation	Range
1. GEFT Field Independence	1640	14.14	6.07	0 - 32
2. MPI Extraversion	1190	30.89	7.05	2 - 48
3. MPI Neuroticism	1190	12.76	9.11	0 - 44
4. EPI Extraversion	457	13.10	3.11	3 - 20
5. EPI A Neuroticism	457	5.66	3.43	0 - 19
6. EPI A Lie Score	457	3.42	1.76	0 - 8
7. EPI B Extraversion	1285	16.73	2.95	4 - 24
8. EPI B Neuroticism	1285	5.97	3.50	0 - 18
9. EPI B Lie Score	1285	1.53	1.44	0 - 7
10. AQT	1668	84.82	10.68	49 - 112
11. MCT	1667	59.65	7.59	5 - 76
12. SAT	1667	21.95	5.38	1 - 89
13. BI	1668	41.90	12.06	10 - 93
14. FAR	1663	6.35	1.32	2 - 9
15. Pass = 1/Separate = 0	1692	.65	.48	0 - 1

TABLE 10

Descriptive Statistics for Experimental Variables for Student Naval Flight Officers (NFO's)

Variables	N	Mean	Standard Deviation	Range
1. GEFT Field Independence	684	13.62	6.03	0 - 32
2. MPI Extraversion	526	29.88	7.19	7 - 44
3. MPI Neuroticism	526	13.66	9.25	0 - 43
4. EPI A Extraversion	169	12.30	3.75	2 - 23
5. EPI A Neuroticism	169	6.33	4.12	0 - 20
6. EPI A Lie Score	169	3.65	1.59	0 - 7
7. EPI B Extraversion	601	16.09	3.30	5 - 25
8. EPI B Neuroticism	601	6.34	3.88	0 - 20
9. EPI B Lie Score	601	1.53	1.36	0 - 8
10. AQT	711	85.60	10.00	57 - 111
11. MCT	711	56.77	8.21	28 - 75
12. SAT	711	19.76	5.61	4 - 30
13. BI	710	34.96	13.14	0 - 67
14. FAR	710	5.34	1.56	1 - 9
15. Pass = 1/Separate = 0	721	0.72	0.45	0 - 1

TABLE 11

Correlation Matrices Comparing Tests of Extraversion/Neuroticism with Field Independence in Two Types of Aviation Students

Variable		PILOTS (NAOC'S) EPI-B E	EPI-B N	EPI-B L	MPI E	MPI N	NON-PILOTS (NFOC'S) EPI-B E	EPI-B N	EPI-B L	MPI E	MPI N
Field Independence	(FI)	-.077	-.018	-.027	-.054	-.053	.067	.001	.005	.020	.020
Extraversion	(E)		-.219	-.094	.578	-.186		-.152	-.050	.605	-.155
Neuroticism	(N)			-.237	-.216	.650			-.250	-.216	.660
Lie Score	(L)				-.025	-.202				.031	-.210
Extraversion	(E)					-.202					-.256
Neuroticism	(N)										

Where N=818: $r_{.001}=.115$*; $r_{.01}=.090$; $r_{.05}=.069$; $r_{.10}=.058$

N=416: $r_{.001}=.161$; $r_{.01}=.127$; $r_{.05}=.096$; $r_{.10}=.081$

		PILOTS EPI-B E	EPI-B N	EPI-B L	EPI-A E	EPI-A N	EPI-A L	NON-PILOTS EPI-B E	EPI-B N	EPI-B L	EPI-A E	EPI-A N	EPI-A L
Field Independence	(FI)	-.105	-.075	-.019	-.095	.007	-.078	.062	-.042	-.118	.057	-.097	-.077
Extraversion	(E)		-.253	-.038	.614	-.288	-.082		-.288	-.070	.638	-.391	-.225
Neuroticism	(N)			-.221	-.148	.653	-.273			-.160	-.099	.628	-.095
Lie Score	(L)				.028	-.112	.356				.008	-.068	.313
Extraversion	(E)					-.193	-.049					-.316	-.262
Neuroticism	(N)						-.218						.095
Lie Score	(L)												

Where N=381: $r_{.001}=.169$; $r_{.01}=.132$; $r_{.05}=.101$; $r_{.10}=.085$

N=140: $r_{.001}=.279$; $r_{.01}=.219$; $r_{.05}=.166$; $r_{.10}=.140$

Note.–Reliability coefficients are underlined.

*Two-tailed significance values of r for P <.001.

scores were negatively correlated with neuroticism and to some extent negatively correlated with extraversion (the latter relationship, while generally negative, was significant [$P < .05$] in only three out of 12 comparisons).

The results of the multiple regression analyses showed that AQT, field independence, and low neuroticism scores were positively related to success in training for the NFO group ($P < .01$, $N = 590$). Mechanical comprehension (MCT), field independence, and low neuroticism scores were related to success for the AOC's ($P < .01$, $N = 1199$). In the cross-validation groups ($N =$ 573 and 1265, respectively), the same variables were also significantly related to success ($P < .01$).

Table 12 contains the means and standard deviations for the cross-validation groups for the Aviation Selection Test variables, as well as Form B of the EPI. These groups do not differ in any important way from the two described in Tables 9 and 10. Tables 13 and 14 show the correlations of the personality test scores with the Aviation Selection Tests. In both groups, correlations between field independence and tests of mechanical (MCT) and general intelligence (AQT) were significant. Further, the Biographical Inventory was positively related to extraversion and negatively related to neuroticism. In the NFO group (Table 14), extraversion was negatively related to field independence, unlike what was reported in Table 11 for a similar NFO group. Other interrelationships may be seen.

TABLE 12

Means and Standard Deviation for Two Cross Validation Groups of Student Aviation Personnel

Variable	AOC Group N=1265		NFO Group N=573	
	Mean	Standard Deviation	Mean	Standard Deviation
1. Field Independence	13.99	6.05	13.76	6.10
2. Extraversion	16.76	2.92	16.39	3.00
3. Neuroticism	5.90	3.63	6.17	3.85
4. Lie Score	1.50	1.49	1.63	1.45
5. AQT	84.96	10.68	85.97	10.24
6. MCT	59.70	7.53	57.05	8.27
7. SAT	22.02	5.07	19.81	5.72
8. BI	42.26	12.30	35.76	13.06
9. FAR	6.40	1.33	5.46	1.59
10. Pass (proportion)	.69	--	.79	--

TABLE 13

Correlation Matrix for Experimental Variables for Student Pilots (AOC's)

Variable	1	2	3	4	5	6	7	8	9
1. Field Independence		-.053	.009	-.010	.258	.244	.127	-.012	.146
2. Extraversion			-.196	-.006	-.101	-.149	-.044	.115	-.039
3. Neuroticism				-.238	.015	-.034	.057	-.114	-.047
4. Lie Score					-.101	-.062	-.086	.073	-.046
5. AQT						.387	.188	-.062	.089
6. MCT							.172	-.012	.117
7. SAT								-.018	.047
8. BI									.076
9. Pass/Separate									

Where N = 1265 - $r_{.001} = .093$*; $r_{.01} = .073$; $r_{.05} = .057$; $r_{.10} = .046$

*Two-tailed significance values of r for $P < .001$

TABLE 14

Correlation Matrix for Experimental Variables for Student Naval Flight Officers (NFO'S)

Variable	1	2	3	4	5	6	7	8	9
1. Field Independence		-.107	-.017	-.032	.263	.280	.166	-.004	.175
2. Extraversion			-.202	-.001	-.106	-.185	-.086	.138	.019
3. Neuroticism				-.230	-.012	-.021	.015	-.184	-.070
4. Lie Score					-.140	-.099	-.045	.082	-.012
5. AQT						.334	.125	-.098	.187
6. MCT							.276	.084	.128
7. SAT								.141	.105
8. BI									-.007
9. Pass/Separate									

Where N = 573 - $r_{.001}$ = .138*; $r_{.01}$ = .108; $r_{.05}$ = .082; $r_{.10}$ = .069

*Two-tailed significance values of r for $P < .001$

Discussion

The results of this study provide normative data for extraversion, neuroticism and field independence scores for two groups of student Naval aviation personnel. Although statistically significant differences between groups were obtained for these variables, and for the Aviation Selection Test scores, the practical significance of the differences depends in large part on the use to be made of these data. For example, in secondary selection using multiple regression techniques (where scores on many variables for many subjects are compared against a criterion of pass/not pass) prediction statements which are even slightly better than chance can provide savings in training costs and be advisory for the students, as well.

On the other hand, mean differences of less than five percentile points as obtained here are probably of small importance in most other circumstances (e.g., in describing differences between these groups).

The relatively higher mean scores for extraversion obtained by this population support the popular view that aviators are extraverted individuals. However, extraversion scores on these tests were not predictive of training success; thus, the high scores on the extraversion dimension seem to be associated mainly with volunteering for aviation training. However, the possibility that the relationship between training success and the extravert continuum is non-linear should be studied. For example, in the present study, the relationships of extraversion to field independence was usually negative and significant (Tables 11, 13, and 14), but in two different groups of NFO's (Table 11) the relationship was positive (four correlations). These latter correlations, while not significantly

different from zero, were significantly different ($P < .01$) from the obtained values in the AOC groups. To check further on this relationship, a scatterplot was made of field independence and extraversion scores[2] and the scatterplot appeared to show that extreme scores (high <u>and</u> low) on field independence were accompanied by extreme scores (high <u>or</u> low) on extraversion. Sixty persons who obtained a field independence score more than a standard deviation above or below the mean of their group (N = 250) were preselected (on that variable only) for further study. The field independence scores, as well as the extraversion scores of these subjects were then converted to deviations from the group's mean, and the sign of the deviation was ignored. The obtained correlation between these converted scores was $r = .74$, indicating that relatively more extreme field independence scores (high and low) tend to be accompanied by extreme extraversion scores also, and the latter are as likely to be high as low. ($P < .01$)

In view of the findings by Green (1963) it was not surprising that high neuroticism scores were predictive of lack of success, even though the comparison made by Green was between voluntary withdrawal and whether a person was still within the training program one year later[3], whereas in the present study, separation (for any reason) was compared with actual completion. In the present study, success in training was also compared with type of separation, and this analysis showed that high neuroticism scores

[2]This group (N = 250) is distinct from all groups previously described. They represent a population on whom the disposition of training success was not yet known, since they were only recently tested.

[3]Almost all separations occur within the first 12 months.

were more likely related to "failure" (i.e., academic and flying failure) than to voluntary withdrawal.

Regarding field independence scores, it was hypothesized that an ability to separate figure from ground (and additionally be able to alternate figure and ground) and ignore seat-of-the-pants cues when appropriate, are important skills for flying aircraft. For example, in flight there are a number of documented incompatible control/display relationships which a pilot monitors simultaneously (viz., gyro horizon and VOR indicator), as well as other attendent problems from disorientation, vertigo and motion sickness (Graybiel, 1951, 1956). Field independent persons appear to be less compelled to attend to inappropriate fields (Witkin et al., 1954, 1962), and it was felt that this capability would afford some advantage for aviation training success. The significant results obtained from the GEFT are encouraging, and future research appears warranted. For example, the correlation between intellectual abilities scores (AQT and MCT) and field independence, point out that common factors related to flight training success exist. Also, the Group Embedded Figures Test is truly a cognitive test, as opposed to a potentially fakeable personality inventory. However, it is also a group-administered test, and as such, possesses the economical advantage of mass testing. It is felt that future research should study the flight training predictive utility of a longer (presently 20 minutes) test. Although it is assumed that field independence and neuroticism scores are valid measures of these traits, it is interesting that both variables are apparently related in the same ways to flight training success for two different kinds of aviation training (pilot and non-pilot),

even though the other cognitive scores (e.g., verbal and arithmetic [AQT] versus mechanical [MCT] intelligence) have differential predictive ability, depending on the type of training program. Future study of this similarity might prove fruitful in identifying some general training success construct (e.g., the "winner" notion of Bale, 1971, personal communication). In addition, other aviation specialties, where field independence might be a useful trait (e.g., air traffic controller, sonar men), should be investigated.

The negative relationship between extraversion and field independence supports the finding reported elsewhere (Evans, 1967), although the relationship was lower than was obtained by Evans, and in two groups of NFO's (four correlations in Table 11) was positive. The correlation between extreme scores on tests of extraversion and field independence (reported above) suggests the relationships between these traits as measured by these tests, is not a simple one.

The present population is extremely homogenous in age, IQ, sex, education, interests, etc., as well as their exposure history (cf. Experiment I, Part II). Because of this, it is felt that the relationships reported here are more likely to be conservative than if the sample were more heterogenous. Thus, the significant relationship between extraversion and neuroticism is probably real, and those constructs may not be exactly orthogonal. However, others (Buros, 1965, item 138) have suggested that in restricted samples, occasionally scores on these traits are found to be negatively correlated.

The reliabilities obtained between forms of these tests (EPI and MPI) were lower for both traits than is reported by others (Buros, 1965, item 138), and

may also be due to the homogeneity of thc present population.

Summary

The personality types of Field Independence and Extraversion appear to share common attributes. Norms for a group-administered version of the former are not available. In addition, some of the attributes of both traits appear to be what folklore suggests are characteristics of aviators (e.g., outgoing, independent, flexible and not situation-bound, autonomous). Thus, it seemed reasonable to study whether scores on tests of these personality dimensions might be related to success in aviation training.

The Group Embedded Figures Test (GEFT) was used to provide field independence scores and the Eysenck Personality Inventory, Form B (EPI-B), served as the main measure of extraversion/neuroticism. Two other tests of extraversion/neuroticism were also employed (EPI-A and Maudsley Personality Inventory).

The population (N = >4,000) was divided into two groups in order to be able to cross validate the findings. Two-thirds of both groups were student pilots (Naval Aviation Officer Candidates - AOC's), and one-third were Naval Flying Officers (NFO's) (navigators, radar intercept operators).

The results showed that field independence, but not extraversion scores, were related to success in aviation training ($P < .01$). In addition, low neuroticism scores were also predictive ($P < .01$) of success for both AOC and NFO groups. These findings were replicated in the cross validation samples ($P < .01$). Regression analyses indicated that these variables would add unique variance to a multivariable prediction equation already in use. The implementation of both variables would appreciably ($P < .01$) improve the existing formula for predicting

separation (secondary selection) from aviation training.

Correlations between extraversion and field independence tended to be negative, but this relationship was not clear cut. The populations' extraversion and neuroticism scores were significantly higher and lower, respectively, than published norms. Test/retest reliabilities of EPI and MPI were low. The implication of these findings are discussed. Further, norms and reliabilities for these tests are presented and the differences in personality profiles between AOC's and NFO's are reported.

References

Ambler, R. K. Selection of aviation personnel: Psychological selection. In U. S. Naval Flight Surgeon's Manual, Washington, D. C., U. S. Government Printing Office, 1968, 629-635.

Bale, R. M. Personal communication, 1970.

Berkshire, J. R., Wherry, R. J., Jr., & Shoenberger, R. W. Secondary selection in Naval aviation training. Educational and Psychological Measurement, 1965, 25, 1 191-198.

Buros, O. K. (Ed.) The sixth mental measurements yearbook. Highland Park, N. J.: Gryphon Press, 1965.

Cullen, J. R., Harper, C. R., & Kidera, G. J. Perceptual style differences between airline pilots and engineers. Aerospace Medicine, 1969, 30, 407-408.

Evans, F. J. Field independence and the Maudsley Personality Inventory. Perceptual and Motor Skills, 1967, 24, 526.

Eysenck, H. J. The scientific study of personality. New York: MacMillan, 1952.

Eysenck, H. J. The structure of human personality. New York: Wiley, 1953.

Eysenck, H. J. The dynamics of anxiety and hysteria. New York: Praeger, 1957.

Eysenck, H. J. Manual of the Maudsley Personality Inventory. London: University of London Press, 1959.

Eysenck, H. J. Experiments in motivation. New York: MacMillan, 1964.

Eysenck, H. J., & Eysenck, S. B. G. Manual for the Eysenck Personality Inventory. San Diego, Calif.: Educational & Industrial Testing Service, 1963.

Fleischman, H. L., Ambler, R. K., Peterson, F. E., & Lane, N. E. The relationship of five personality scales to success in Naval aviation training. Pensacola, Fla.: Naval Aerospace Medical Institute, NAMI-968, 1966.

French, J. W., Ekstrom, R. B., & Leighton, A. P. Manual for kit of reference tests for cognitive factors. Princeton, N.J.: Educational Testing Service, 1963.

Graybiel, A. Spatial disorientation in flight. Pensacola, Fla.: Naval School of Aviation Medicine, NM 001 059.01.24, 1950.

Graybiel, A. Problems involving the pilot and his task. Journal of Aviation Medicine, 1956, 27, 397-406.

Green, L. R. An exploratory investigation of the relationship between four personality measures and voluntary resignation from aviation training. Pensacola, Fla.: Naval School of Aviation Medicine, NSAM-487, 1963.

Jackson, D. N., Messick, S., & Myers, C. T. Evaluation of group and individual forms of embedded-figures measures of field-independence. Educational and Psychological Measurement, 1964, 24, 177-192.

Peterson, F. E., & Lane, N. E. The relationship of college major to success in Naval aviation training. Pensacola, Fla.: Naval Aerospace Medical Institute, NAMI-958, 1966.

Peterson, F. E., Lane, N. E., & Kennedy, R. S. The relationship of the Edwards Personal Preference Schedule to success in Naval flight training. Pensacola, Fla.: Naval Aerospace Medical Institute, NAMI-946, 1965.

Shoenberger, R. W. Personality orientation and success in Naval aviation training. Pensacola, Fla.: Naval School of Aviation Medicine, NSAM-881, 1963.

Voas, R. G., Bair, J. T., & Ambler, R. K. Validity of personality inventories in the Naval aviation selection program. Pensacola, Fla.: Naval School of Aviation Medicine, NSAM-300, 1957.

Witkin, H. A. Perception of body position and of the position of the visual field. Psychological Monographs, 1949, 73, 7, 302.

Witkin, H. A. Individual differences in ease of perception of embedded figures. Journal of Personality, 1950, 19, 1-15.

Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. R., & Karp, S. A. Psychological differentiation: Studies of development. New York: Wiley, 1962.

Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Meissner, P. B., & Wagner, S. Personality through perception. New York: Harper's, 1954.

Appendix B

Three Studies of Induced Changes in Potential of Electro-oculographic Recording Due to Light and Accompanying Bibliography

Introduction

Electro-oculography, electro-nystagmography, electro retinogram corneo-retinal potential and their acronyms (EOG, ENG, ERG and CRP) refer to methods of recording electric potentials from the eye, but some confusion exists in their use. EOG, ENG, and CRP are very similar. The EOG and ENG are recordings of changes in position of the dipole formed by the potential differences in charge between the cornea and the retina (CRP). Electro retinograms are recordings of electric potentials which originate in the retina in response to light. A good review of the ERG literature may be found in Riggs (1958, 1967). A number of authors have surveyed the important studies of EOG and CRP recording (Miles, 1939b; Marg, 1951; Rashbass, 1960).

The term corneoretinal potential CRP) was used by Miles in a series of studies (Miles, 1929, 1938, 1939a, 1939b, 1939c, 1939d, 1940), and otolarngologists and others interested in vestibular functions have used this term and electro nystagnography (ENG)[1] to refer to the technique they employ to measure eye movements. Electro-oculography, as a descriptive term, has been preferred by ophthalmologists and other students of visual science. Index Medicus uses the latter as a key word, and very few corneoretinal potential studies are referenced therein.

The origin of a large part of the potential differences recorded by EOG/CRP techniques is probably the pigment epithelium (Iamazumi, 1964, 1966; Steinberg, 1970a, 1970b). This potential is very likely produced by the "steady state

[1] Richter, 1964, calls it PONG.

transport processes across the pigment epithelium" (Steinberg, 1972, personal communication). However, from intracellular recordings in cat, the origin of the c wave of the ERG has also been shown to be the pigment epithelium (Steinberg, Schmidt & Brown, 1970). The similarities in site of origin of these two recording methods suggest that confusion can result in their use, and perhaps CRP would be a better term than EOG or ENG.

The literature which deals with fluctuations in the corneoretinal potential (by that name) as a function of the adaptive state of the retina is meager (Miles, 1929, 1938, 1939a, 1939b, 1939c, 1939d, 1940), but a number of studies have appeared which describe EOG changes with luminance (most of the references reported in the bibliography listed here).

Because a frequently employed experimental procedure in vestibular studies involves taking an experimental subject from a lighted laboratory and placing him in the dark, it was felt that a study which addressed itself to this procedural problem would have some utility for vestibular research, in particular, and eye movement studies, in general.

In addition to bringing together in one source the EOG, ENG and CRP studies which deal with changes in the potential due to luminance, this report had a secondary purpose: To report on a series of empirical studies which investigated how much dark adaptation is required for acceptable stabilization of an EOG recording.

Method and Results

Procedure I

Standard EOG/CRP records were made on a Beckman EEG recorder, with silver electrodes. The general method has been described best by Ford & Leonard (1958), and also by others (e.g., Kris, 1958a, 1958b; Marg, 1951; Norris, 1967; Perlman, 1939). Only lateral eye movements were recorded in this study. A 2.5-second time constant (AC) was used because of difficulties cited by Turksy & O'Connell (1966) with shorter time constants.

Data were obtained from one subject. After adapting to ambient room illumination (about 100 foot candles) for one hour, the subject looked between two pinpoint lights of low luminance which were separated by a visual angle of 20°. The initial deflections obtained were taken to be the baseline. The room lights were then extinguished and a calibration was obtained every minute for 30 minutes. The room lights were then turned on and eye movements again were measured every minute for 30 minutes.

Figure 14 shows amount of deviation plotted as a function of lighting conditions. When the room lights were extinguished, the mm deviation decreased, but recovered within about 20 minutes. Turning the lights on resulted in an increase in the amount of pen deflection per eye movement, but again recovery to approximate base line occurred. Others (Iamazumi, 1964) have obtained similar data and Homer & Kolder (1966, 1967a, 1967b, 1967c) have used a fourth order polymomial equation to describe the function of the relationship of luminance to CRP over time.

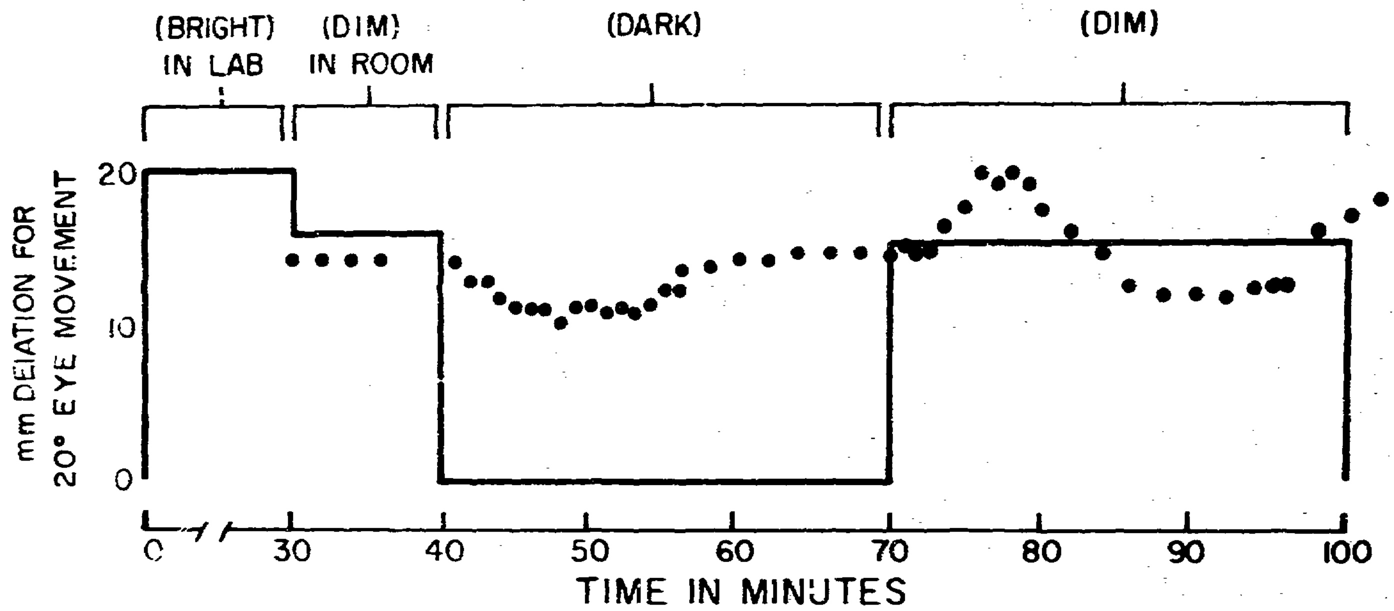


FIGURE 14. CHANGES IN POTENTIAL FOR 20° EYE MOVEMENTS RECORDED IN LIGHT AND DARK

Procedure II

It is not obvious if vestibular stimulation should produce an effect on the corneoretinal potential. However, vestibular stimulation is a well known soporific. Perhaps drowsiness could alter pupil size and directly or indirectly influence the CRP. To solve the applied methodological problem of recording nystagmus during long periods in the dark, it was decided to examine CRP changes in several subjects (N = 7) during whole body sinusoidal oscillation for 30 minutes in the dark. The oscillation parameters were 50^{o} displacement and 30 cpm (.5 cps).

The subject's eye movements were calibrated with the lights on and that average value was taken as 100%. The room lights were then extinguished and six calibrations were made every five minutes for each subject while oscillation persisted. Figure 15 shows that, as before, an initial drop occurred and a recovery appeared to be present after about 20 minutes. Figure 16 shows that no systematic change occurs within a calibration period.

Procedure III

To check further on CRP changes with time in the dark, the 50 subjects described in Experiment I again were adapted for ambient room (laboratory) luminance, and were then tested on three occasions: (a) After two to three minutes in the dark, (b) after 20 minutes in the dark, and (c) after 70 minutes in the dark. Between the second and third calibration period, the subjects were oscillated for 50 minutes (75^{o} displacement; 12 cpm).

Significant differences between the first and second calibration periods

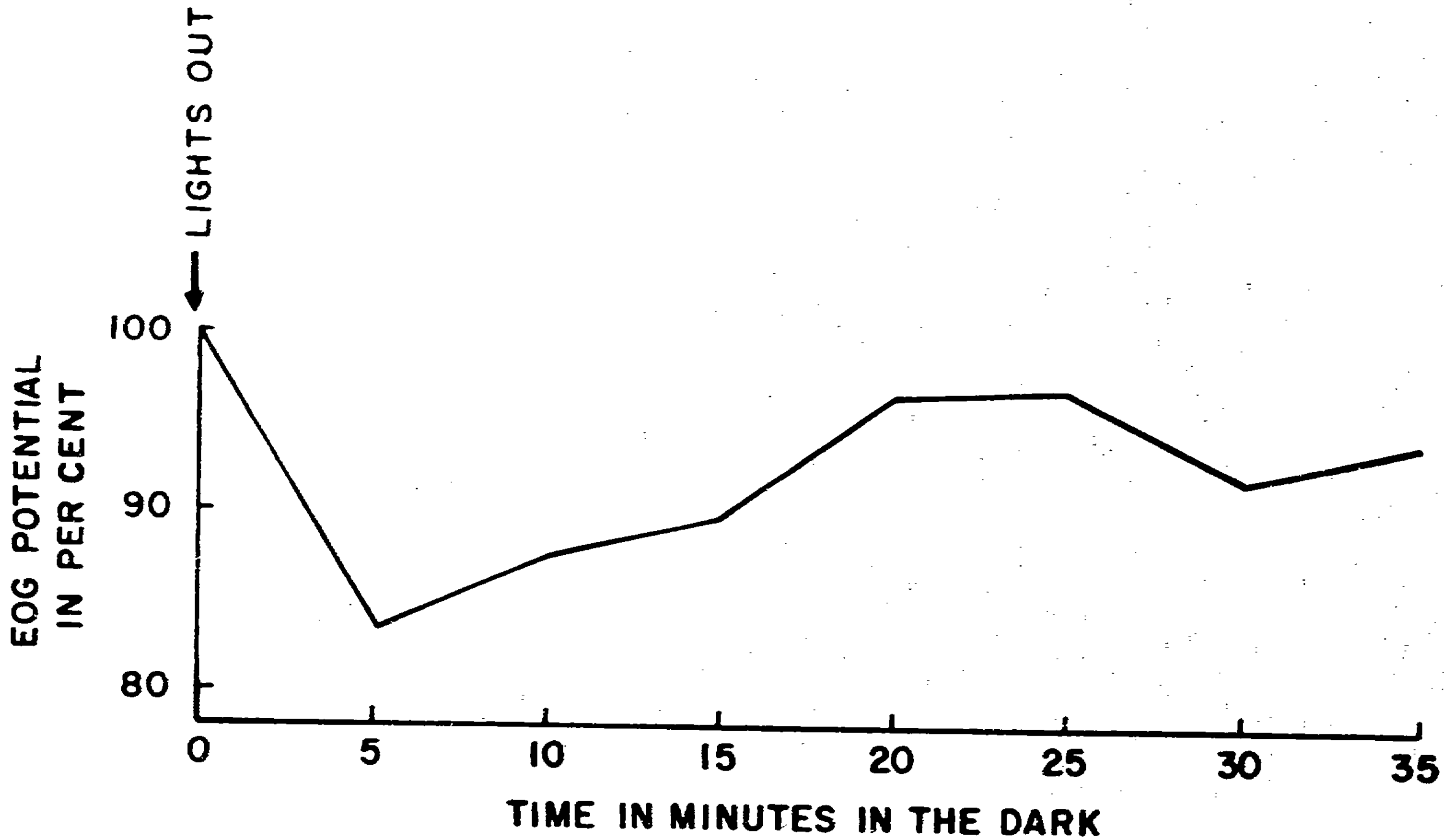


FIGURE 15 CHANGES IN RECORDED POTENTIAL WITH TIME IN THE DARK FOR SEVEN SUBJECTS

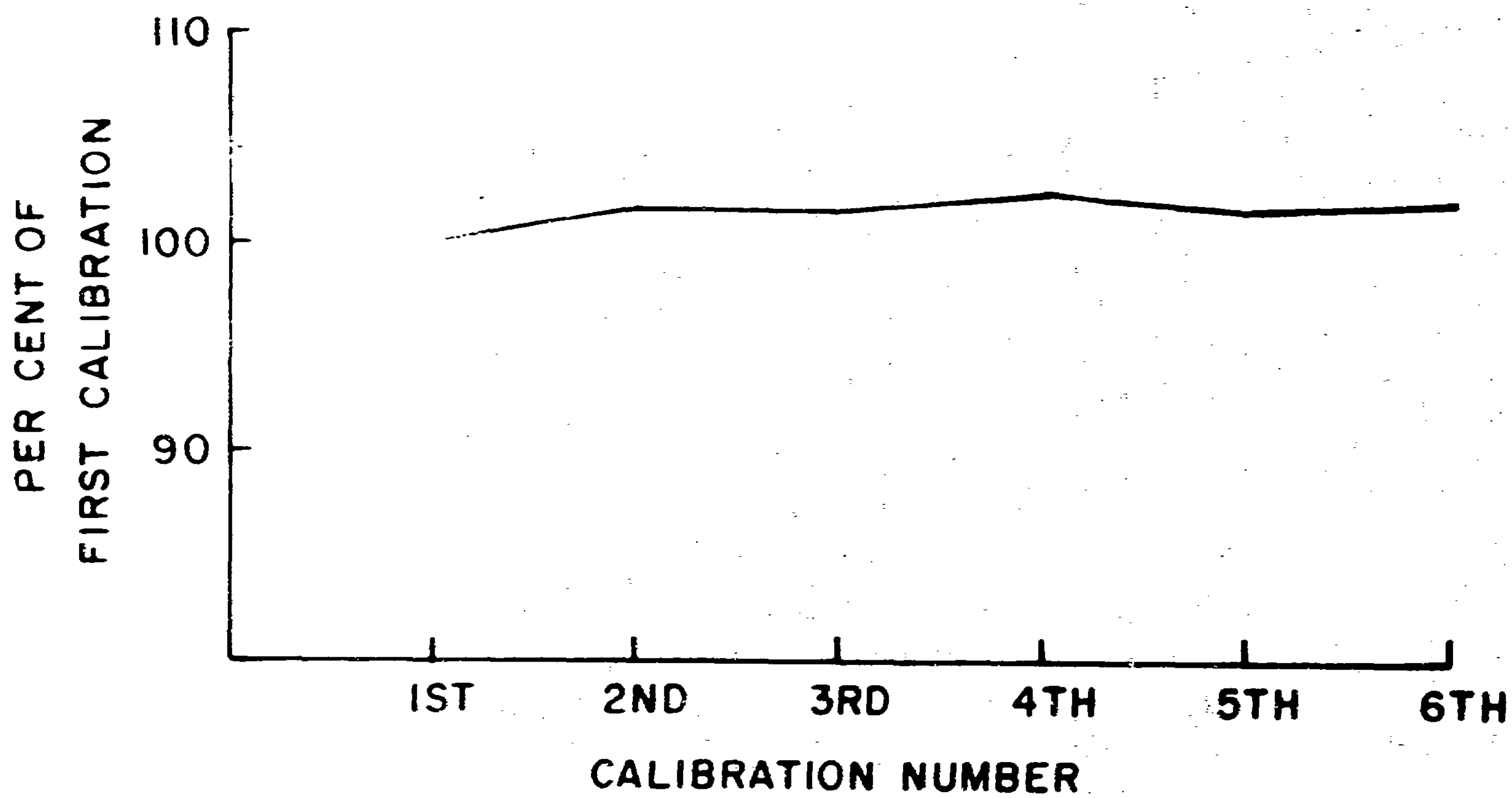


FIGURE 16. CHANGES IN RECORDED POTENTIAL WITHIN A CALIBRATION SESSION FOR SEVEN SUBJECTS

were obtained ($P < .01$), and this is to be expected because of the drop in potential which occurs when light is removed (the first being lower). The difference between the second and third calibration period was not significantly different from zero ($P > .3$). Calibrations were not obtained under room illumination because of the other constraints of a longer experimental procedure of which this was a part.

Discussion and Conclusions

The results of this study are in accord with the findings in the literature (cf bibliography). After the eye has been adapted at a specific luminance level, the corneo retinal potential will change when luminance is changed. If luminance is reduced, the potential drops immediately, but a recovery essentially to the initial level occurs in about 20 - 30 minutes, even though no change in ambient conditions are made. Under Procedure III, it is likely that the significant difference between the first and second calibration is due to the early drop in potential during the first calibration. Apparently after 20 minutes the eye reached a relatively steady adaptive level which did not change appreciably by 70 minutes.

From a practical standpoint, particularly for vestibular investigations, this study showed that 20 minutes of dark adaptation should be allowed to control for the effects of changes in CRP with time in the dark, particularly when nystagmus amplitude is a variable of interest.

Checks for systematic changes were made in Experiment II within a calibration period. While none were found, this does not rule out the possibility that some might occur between calibration periods.

It is felt that since CRP appears to be sensitive to changes in the adaptive level of the retina whether the changes are induced by light or by breathing different gas mixtures (Fenn, Galambos, Otis & Rahn, 1949), perhaps this method should be explored further for its use as an index of the adaptive level of the eye under conditions where ERG is difficult to perform.

References

Adler, F. H. Pathologic physiology of convergent strabismus. AMA Archives of Ophthalmology, 1945, 33, 362.

Arden, G. B., & Barrada, A. Analysis of the electro-oculograms of a series of normal subjects. British Journal of Ophthalmology, 1962, 46, 468-481.

Arden, G. B., & Kelsey, J. H. Changes produced by light in the standing potential of the human eye. Journal of Physiology, 1962, 161, 189-204. (a)

Arden, G. B., & Kelsey, J. H. Some observations on the relationship between the standing potential of the human eye and the bleaching and regeneration of visual purple. Journal of Physiology, 1962, 161, 205-226. (b)

Arden, G. B., Barrada, A., & Kelsey, J. H. New clinical test of retinal function based upon the standing potential of the eye. British Journal of Ophthalmology, 1962, 46, 449-467.

Aserinsky, E. Effects of illumination and sleep upon amplitude of electro-oculogram. AMA Archives Journal of Opthalmology, 1955, 53, 542-545.

Baudouin, A., Fischgold, H., Causse, R., & Lerique, J. Une vieille notion trop oubliee: l. La difference de potentiel retinocorneenne. Son interet theoriqeu et pratique. Bulletin et l Academie de Medicine, 1939, 121, 688-693.

Bergmann, F. The inhibitory effect of light on central and optokinetic nystagmus in the rabbit. Confinia Neurologica, 1955, 25, 403-412. (a)

Bergmann, F. Asymmetric inhibitory effect of light on labyrinthine nystagmus in the rabbit. Confinia Neurologica, 1955, 25, 413-423. (b)

Bergman, P. S., Nathanson, M. B., & Bender. Electrical recordings of normal and abnormal eye movements modified by drugs. AMA Archive of Neurology and Psychology, 1952, 67, 357-374.

Brockhurst, R. J., & Lion, K. S. Analysis of ocular movements by means of an electrical method. AMA Archives Journal of Ophthalmology, 1951, 46, 311-314.

Brown, K. T., & Wiesel, T. N. Intraretinal recordings in the unopened cat eye. American Journal of Ophthalmology, 1958, 46, 291-298.

Burian, H. M., & Jacobson, J. H. (Eds.) Clinical Electroretinography. Oxford: Pergamon Press, 1966.

Byford, G. H. An eye movement recorder and its application to the study of visual illusions of rotation. Biomedical Sciences Instrumentation, 1964, 2, 53-64.

Callahan, A., & Redlich, F. C. Electro-encephalography and ophthalmology. American Journal of Ophthalmology, 1946, 29, 1522.

Carmichael, L., & Dearborn, W. F. Reading and visual fatigue. Boston: Houston Mifflin Co, 1947.

Davis, J. R., & Shackel, B. Changes in the electro-oculogram potential level. British Journal of Ophthalmology, 1960, 44, 606-618.

Dewar, J. The physiological action of light. Nature, (London), 1877, 15, 433-435.

Dewar, J., & McKenrick, J. G. On the physiologic action of light, I and II. Journal of Anatomy and Physiology, 1873, 7, 273-281. (a)

Dewar, J. & McKenrick, J. G. Recent researchers on the physiologic action of light. Nature, (London), 1873, 8, 204-205. (b)

Dowd, P. J. Factors affecting the quality of the electronystagmograms in vestibular stimulation, Brooks AFB, Texas, SAM-TR-65-68, 1968.

Dzendolet, P. Standing potentials of the frog's eye. Journal of the Optical Society of America, 1960, 50, 551-555.

Fenn, W. O., Galambos, R., Otis, A. B., & Rahn, H. Corneoretinal potential in anoxia and acapnia. Journal of Applied Physiology, 1949, 1, 710-716.

Fenn, W. O., & Hursh, J. B. Movements of the eye when the lids are closed. American Journal of Physiology, 1937, 118, 8.

Ford, A., & Leonard, J. L. Techniques for recording surface bioelectric currents. San Diego, Calif, Naval Electronics Laboratory, #839, 1958.

Francois, J., Verriest, G., & DeRouck, A. Modification of the amplitude of the human electro-oculogram by light and dark adaptation. British Journal of Ophthalmology, 1955, 39, 398-408.

Geddes, L. A. The measurement of physiologic events by electrical impedance. American Journal of Medical Electronics, 1963, 2, 300-307.

Gouras, P., & Gunkel, R. D. The EOG in chloroquine and other retinopathies. Archives of Ophthalmology, 1963, 70, 629-639.

Halstead, W. C. A method for the quantitative recording of eye movement. Journal of Psychology, 1938, 6, 177-180.

Hoffman, A. C., Wellman, B., & Carmichael, L. A quantitative comparison of the electrical and photographic techniques of eye movement recording. Journal of Experimental Psychology, 1939, 24, 40-53.

Homer, L. D. Non linear response of the human potential to sinusoidal changes in light intensity. Pflüger's Archiv für die gesamte physiologie des menschen und der fiere, 1967, 295, 361-368.

Homer, L. D., & Kolder, H. E. J. The oscillation of the human corneo-retinal potential at different light intensities. Pflüger's Archiv für die gesamte physiologie des menschen und der fiere, 1967, 296, 133-142.

Homer, L. D., Kolder, H. E. J., & Hansjorg. Mathematical model of oscillations in the human corneo-retinal potential. Pflüger's Archiv für die gesamte physiologie des menschen und der fiere, 1966, 287, 197-202.

Homer, L. D., Kolder, H. E. J., Hansjorg, & Benson. Parameter variations of a model of the oscillation of the human corneo-retinal potential. Pflüger's Archiv für die gesamte physiologie des menschen und der fiere, 1967, 294, 103-112.

Horie, E. Acta Ophthalmologica Jap., 1969, 67, 1088. Cited in Imaizumi, 1966.

Imaizumi, K. The clinical application of electro-oculography (EOG). In H. M. Burian & J. H. Jacobson (Eds.) Clinical Electroretinography, Oxford: Pergamon Press, 1966, 311-326.

Imaizumi, K., Takahashi, F., Toyama, T., et al. Electro-oculograms in cases of highly disturbed vision. Journal of Clinical Ophthalmology (Tokyo), 1964, 18, 333-344.

Jacobson, E. Electrical measure of neuromuscular states during mental activities, I: Imagination of movement involving skeletal muscles. American Journal of Physiology, 1930, 91, 567-608. (a)

Jacobson, E. Visual imagery and recollection. American Journal of Physiology, 1930, 95, 694-702. (b)

Kelsey, J. H. Clinical electro-oculography. British Journal of Ophthalmology, 1966, 50, 438-439.

Kelsey, J. H. Variations in the normal electro-oculogram. British Journal of Ophthalmology, 1967, 51, 44-49.

Kolder, H. Pflüger's Archiv für die gesamte phyiologie des menseen und der fiere, 1959, 268, 258-272. Cited in Homer & Kolder, 1967.

Kris, C. A technique for electrically recording eye position. Wright-Patterson AFB, Ohio, WADC Technical Report 58-660, 1958. (a)

Kris, C. Corneo-fundal potential variation during light and dark adaptation. Nature, 1958, 182, 1027-1028. (b)

Leksell, L. Clinical record of eye movement. Acta Chirurgica Scandinavica, 1939, 82, 262-270.

Lindsley, D. B., & Hunter, W. S. A note on the polarity potential from the human eye. Proceedings of the National Academy of Sciences, 1939, 25, 180-183.

Lion, K. S., & Brockhurst, R. J. Study of ocular movements under stress. AMA Archives Journal of Ophthalmology, 1951, 46, 315-318.

Lyman, R. S. Eye movements in the electro-encephalogram. Bulletin of the Johns Hopkins Hospital, 1941, 68, 1-31.

McFarland, R. A., Evans, J. N., & Holperin, M. J. Ophthalmic aspects of acute oxygen deficiency. Archives of Ophthalmology N. S., 1941, 26, 886-913.

McFarland, R. A., Knehr, C. A., & Berens, C. Effects of anoxemia on ocular movements while reading with especial reference to patients with motor anomalies. American Journal of Ophthalmology, 1937, 20, 1204-1221.

Marg, E. Development of electro-oculography. AMA Archives Journal of Ophthalmology, 1951, 45, 169-185.

Merton, P. D. The accuracy of directing the eye and the hand in the dark. Journal of Physiology, 1961, 156, 555-577.

Meyers, I. L. Electronystagmography: A graphic study of the action currents in nystagmus. Archives of Neurology and Psychiatry, 1929, 21, 901-918.

Miles, W. R. Horizontal eye movements at the onset of sleep. Psychological Review, 1929, 36, 122.

Miles, W. R. The polarity potential of the human eye. Science, 1938, 88, 437.

Miles, W. R. Performance of the einthoven galvanometer with input through a vacuum tube microvoltmeter. Journal of Experimental Psychology, 1939, 25, 76-90. (a)

Miles, W. R. Steady polarity potential of human eye. Proceedings of the National Academy of Sciences, 1939, 25, 25-36. (b)

Miles, W. R. Einthoven string galvanometer used with a vacuum tube micro-voltmeter. Scientific Instrument, 1939, 10, 134-136. (c)

Miles, W. R. Experimental modification of the polarity potential of the human eye. Yale Journal of Biology and Medicine, 1939-1940, 12, 160-183. (d)

Miles, W. R. Modification of the human eye potential by dark and light adaptation. (Abstract) Science, 1940, 91, 456.

Mowrer, O. H., Ruch, T. C., & Miller, N. E. The corneoretinal potential differences as the basis of the galvanometric method of recording eye movements. American Journal of Physiology, 1936, 114, 423.

Noell, W. K. Studies on the electrophysiology and the metabolism of the retina. Brooks AFB, Texas, USAF School of Aviation Medicine, 21-1201 0004, Report No. 1, 1953.

Norris, C., & Rubin, W. Notes on nystagmography: Method and calibration. Archives of Otology, 1967, 85, 265-268.

North, A. W. Accuracy and precision of electro-oculographic recording. Investigative Ophthalmology, 1965, 4, 343-348.

O'Meara, D., & Fittow, M. H. Methods of measuring eye movements. American Orthoptic Journal, 1966, 16, 50-56.

Perlman, H. B., & Case, T. J. Nystagmus: Some observations based on an electrical method for recording eye movement. Laryngoscope, 1939, 49, 217-228.

Rashbass, C. New method for recording eye movements. Journal of the Optical Society of America, 1960, 50, 642-644.

Rashbass, C. The relationship between saccadic and smooth tracking eye movements. Journal of Physiology, 1961, 159, 326-338.

Redlich, F. C., Callahan, A., & Schmetic, J. F. Electrical potentials from eye movements. Yale Journal of Biology and Medicine, 1946, 18, 269-274.

Richter, H. R. Photo-electro-nystagmography (PONG) and photo-electro-oculography. Biomedical Sciences Instrumentation, 1964, 2, 65-71.

Riggs, L. A. The human electro-retinogram. AMA Archives Journal of Ophthalmology, 1958, 60, 739-754.

Riggs, L. A. Electrophysiology of vision. In C. H. Graham, et al. (Eds.) Vision and visual perception. New York: Wiley, 1967.

Rosen, S., & Czech, D. The use of electro-oculography for identifying phases of cognitive process. Psychophysiology, 1966, 3, 203-212.

Rosenberg, P. E., & Toglia, J. U. Electro-nystagmography in clinical audiology. Journal of Speech and Hearing Disorders, 1967, 32, 170-176.

Shackel, B. Pilot study in electro-oculography. British Journal of Ophthalmology, 1930, 44, 88-113.

Shackel, B., & Davis, J. R. A second survey with electro-oculography. British Journal of Ophthalmology, 1960, 44, 337-346.

Shanzer, S. The examination of eye movements. Journal of Mount Sinai Hospital, New York, 1966, 16, 236-242.

Steinberg, R. H. Personal communication, 1970.

Steinberg, R. H., Schmidt, R., & Brown, K. T. Intracellular responses to light from the cat's pigment epithelium; origin of the electro-retinographic c wave. Paper presented at the meeting of the Association for Research in Ophthalmology, Sarasota, Fla., 1970.

Appendix C

A Review of Some Attributes of a Vigilance Task

with a Range of Difficulties

Background

A reliable procedure for measuring nystagmus habituation is presented in Appendix E. One way to determine whether nystagmus habituation co-varies with vigilance or alertness would be to obtain an independent measure of alertness and correlate it with nystagmus concomitantly elicited. Mackworth (1970) has suggested this as a profitable line of research, particularly with regard to individual differences.

The general vigilance tasks reported in the literature (see for example Buckner & McGrath, 1963) are not adequate for the purpose of correlating nystagmus and vigilance, since nearly all tasks have too few signals per subject, per session (e.g., nine in 90 minutes), that a fine grain analysis of performance correlated with nystagmus over time is not possible. Additionally, most vigilance tasks reported in the literature are visual, and visual stimuli inhibit nystagmus (Guedry, 1965; Wendt, 1951).

A task which could obviate these shortcomings and be modified for vestibular studies is a little used counting task (Jerison, 1955, 1956). The original idea for the test was suggested to Jerison by J. R. Steele and W. R. Miles (Steele, personal communication, 1970). Miles noticed his inability to keep track of a number of events with different states during his own exposure to a noisy environment[1]. Steele, while working in a nephrology laboratory, observed wide individual differences in several technicians' abilities with

[1]Professor Miles was nearly 70 when this observation was made. Differences reported later in a young and middle aged group suggest age may be an important variable in this type of work.

regard to the number of kidneys they were able to keep track of. Their task was literally to count the number of drips from each kidney that they monitored and technicians appeared to differ in their ability to monitor adequately several kidneys. Using these ideas, Jerison programmed three lights to flash at different frequencies (4.6, 9.6 and 6.5 times per minute in the 1955 study, and 6.3, 12.0 and 4.6 times per minute in the 1956 study) and showed that, in general, performance degraded more under noise than quiet (Jerison, 1955, 1956), but the relationship was not simple (see also Jerison, 1959).

Another study with this task has been conducted by Helper (1957), who also compared performance in noise (110 db) and quiet, but while GSR, heart rate, and muscle tension were recorded (his lights were presented 11.1, 6.7, and 4.6 times per minute). The results of that study (Helper, 1957) showed that noise did not disrupt performance, and in general, mean heart rate was correlated ($P < .05$) with the total number of the subjects' correct responses for a one-hour session ($N = 24$). In addition, skin conductance tended to be higher during the noise conditions, and the author concludes that since performance did not differ in noise and quiet, perhaps performance was maintained in noise at some higher cost physiologically.

Another report of this test (Kennedy, 1971) was largely methodological in nature. Scoring methods, practice effects and visual versus auditory presentation were studied. In that study, four forms of the task (signal rates were 8, 6, and 5 per minute) were administered over four sessions in counter-balanced order to 16 subjects. Three of the forms required auditory monitoring (one, two, or all three tones), and one required visual (three lights) monitoring

(similar to Jerison, 1955, 1956; Helper, 1957). Visual performance was superior to auditory performance; the auditory performance was a function of the number of channels monitored. A ten-minute practice session was given before session I, and no learning effects appeared evident over the four sessions thereafter. Among the six scoring methods used, "percent correct" was considered best. Decrements in performance within sessions were clearcut in all but the three channel auditory test. Intra-task correlations over subjects were high ($r > .75$), while inter-task correlations showed only 20 percent common variance.

In addition to the investigations of Jerison (1955, 1956), Helper (1957) and Kennedy (1971) and those contained in the main body of the present paper (Experiments I and II), several other studies have been conducted with this test which have not yet been published. The presentation of these unpublished studies will be the purpose of this report.

Method and Results

1. Performance in "percent correct" for three channel visual and for three channel auditory monitoring was calculated in two ways for 16 subjects (Kennedy, 1968):

$$\text{(a)}\quad \frac{\Sigma\,\{H_I + H_{II}\}}{\Sigma\,\{H_I + H_{II} + C_I + C_{II} + O_I + O_{II}\}} \quad \text{and}$$

$$\text{(b)}\quad \frac{\Sigma\,\{H_I + H_{II} + H_{III}\}}{\Sigma\,\{H_I + H_{II} + H_{III} + C_I + C_{II} + C_{III} + O_I + O_{II} + O_{III}\}}$$

where H = hits; C = commision errors; C = omission errors; and I, II, and III = low, middle and high tones (channels) respectively.

This analysis was performed in order to determine the reliability of scores obtained by the tallies of all responses of a subject on all three channels versus scoring only the two perfectly regular channels (cf., Figure 7). The results showed that an abbreviated scoring approach resulted in little loss in reliability (r = .96 and .98 for three channel visual and auditory scorings, respectively). This finding suggests that when three channel testing is to be studied, one can avoid recording the subject's responses to the third, slightly irregular, channel. This reduces by about 30 percent the amount of scoring that must be done. In addition, and more important, since the high channel is the only one that is not perfectly regular (cf. Figure 7), it is the only one which necessitates a record of the stimulus in order to be scored validly; the other two do not.

2. Experiment I (Figure 8) showed that two channel auditory vigilance performance was essentially the same whether subjects were tested in the dark during protracted whole-body oscillation or whether tested in an open classroom

in groups of 8 - 12. Another experiment (Moroney & Kennedy, in preparation, a) compared the performances of subjects who were tested in shielded cubicles (N = 67) with the performance of those who were reported on in Experiment II for one-channel monitoring (N = 124). In addition, an attempt was made to influence (i.e., distract) the performance of some of the subjects (N = 27) by permitting them to hear the responses of another subject who responded to a different task from theirs. The results of the three groups are shown in Figure 17. There appeared to be no significant differences between the groups.

3. The effects of practice with distributed ex sure over a longer (90 minutes) session than usual was studied (Moroney & Kennedy, in preparation, b). The procedure required subjects to perform on the three-channel auditory test for ten minutes followed by a five-minute rest period, successively for a total of 90 minutes. These data (Figure 18, N = 30) show that a small improvement occurs between the first and last ten-minute segments, but the difference is probably of small practical importance, and the remainder of the function appears asymptotic.

4. Another study which presents practice effects (Graybiel et al., in preparation) employed the visual version of this test during a 14-day exposure to constant velocity (10 RPM) in a 15-foot-diameter windowless room. The subjects were four young men (23.5 years) who were recently graduated from the Naval Academy, and four other persons with bilateral labyrinthine defects (deaf and no vestibular function), who were also slightly more than ten years older (35 years).

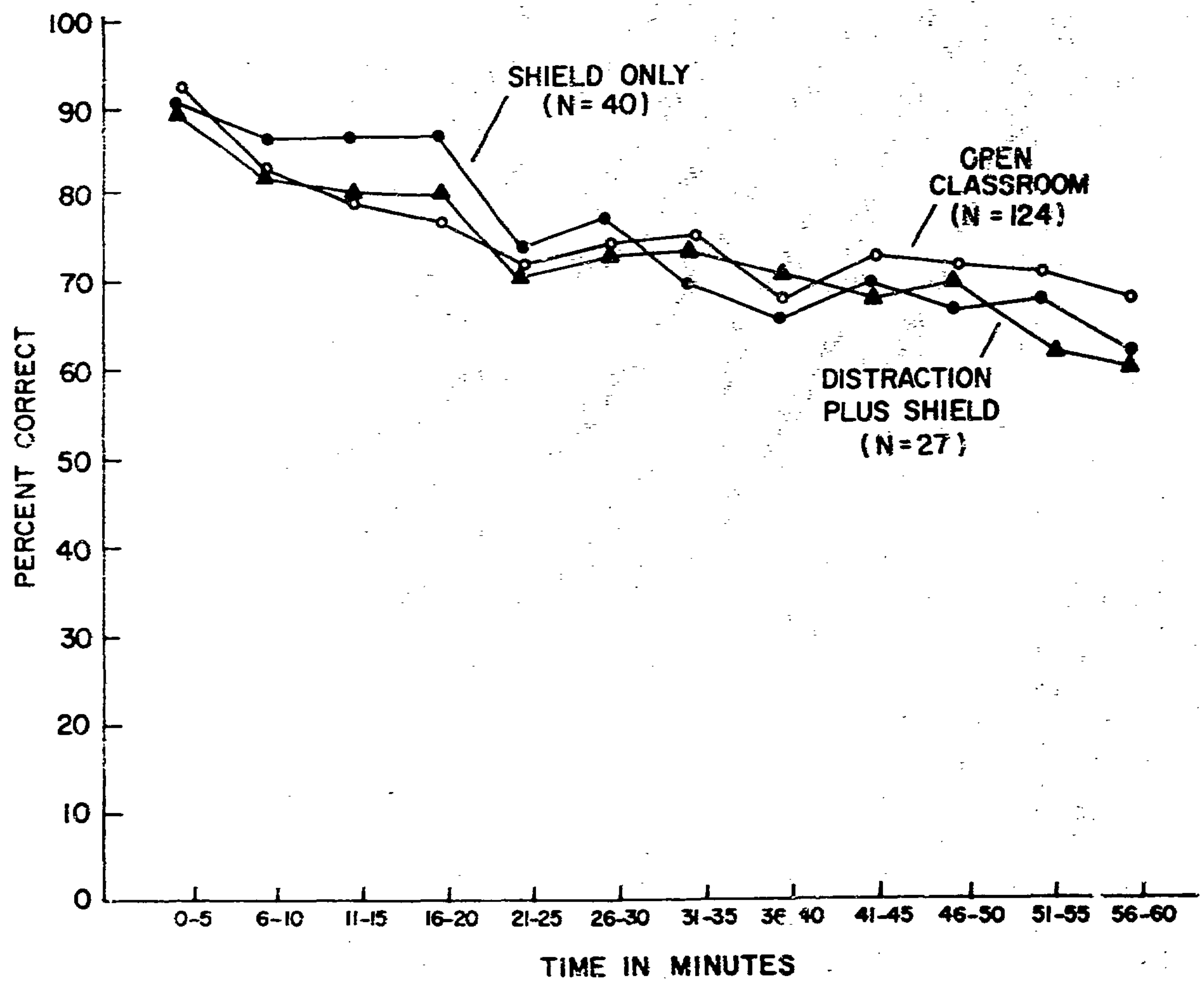


FIGURE 17. ONE-CHANNEL AUDITORY MONITORING PERFORMANCE TESTED UNDER CONDITIONS OF VISUAL ISOLATION, DISTRACTION AND IN AN OPEN CLASSROOM IN GROUPS OF 8-12 SUBJECTS

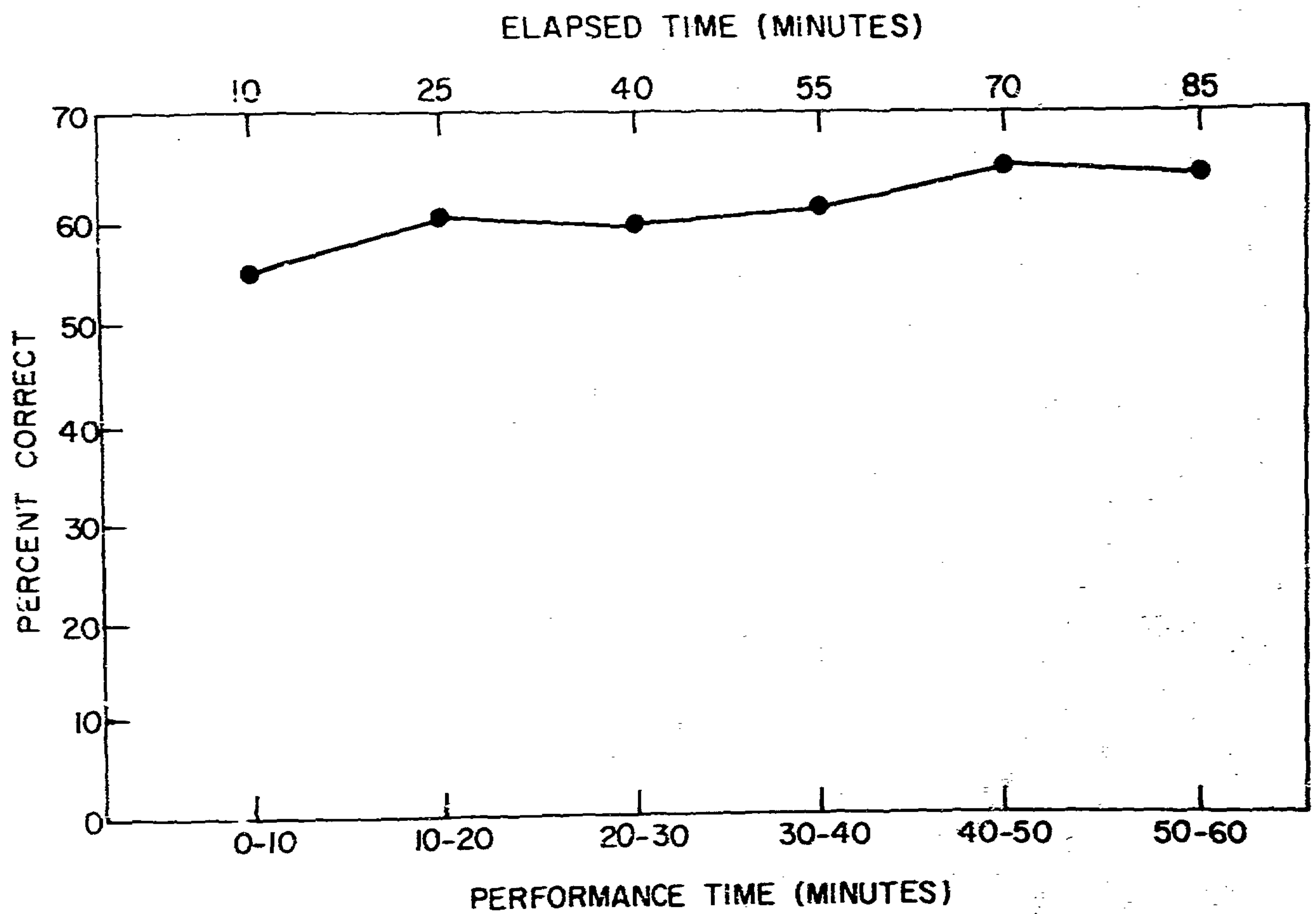


FIGURE 18. PERFORMANCE ON THREE-CHANNEL AUDITORY MONITORING INTERPOLATED BY FIVE MINUTE REST PERIODS (N = 29)

The latter did not become motion sick, and the former did, initially, but recovered. The signal rates were 8, 10, and 12 per minute; the test was taken for 10 minutes each day for the 14 days of rotation, as well as for a few days before and after rotation[2]. The results appear in Figure 19. The overall impression is of a learning curve which is not disrupted by rotation in either group, and poorer performance appeared to be obtained by the labyrinthine defective (and also older) men.

5. In another study (Kennedy & Coulter, 1971), the effects of anticipatory physical threat stress (shock) were studied in 54 subjects, 29 of whom performed the three-channel auditory test, and 35 the one-channel test. The subjects were instructed that at some unspecified period in their watch (the duration of which was also unspecified), they would receive a shock, which was empirically determined on the authors as being "moderately painful". The subjects' performances were compared with those of the one and three-channel auditory control groups already reported in Figure 8 and with both sets of data appear as Figure 20.

It may be seen that one- and three-channel auditory performance appears to benefit from the threat of stress ($P < .05$).

6. The three-channel auditory test again was used (Kennedy, Moroney, Bale, Gregoire, & Smith, in press) during hurricane penetrations (Hurricane Inga) in three different Navy aircraft. Wind velocities were as high as 115 knots; most of the flying in the hurricane area was performed at 500 feet,

[2]Because session length was short each day, this test was not assessing vigilance, but rather an ability to do complex counting.

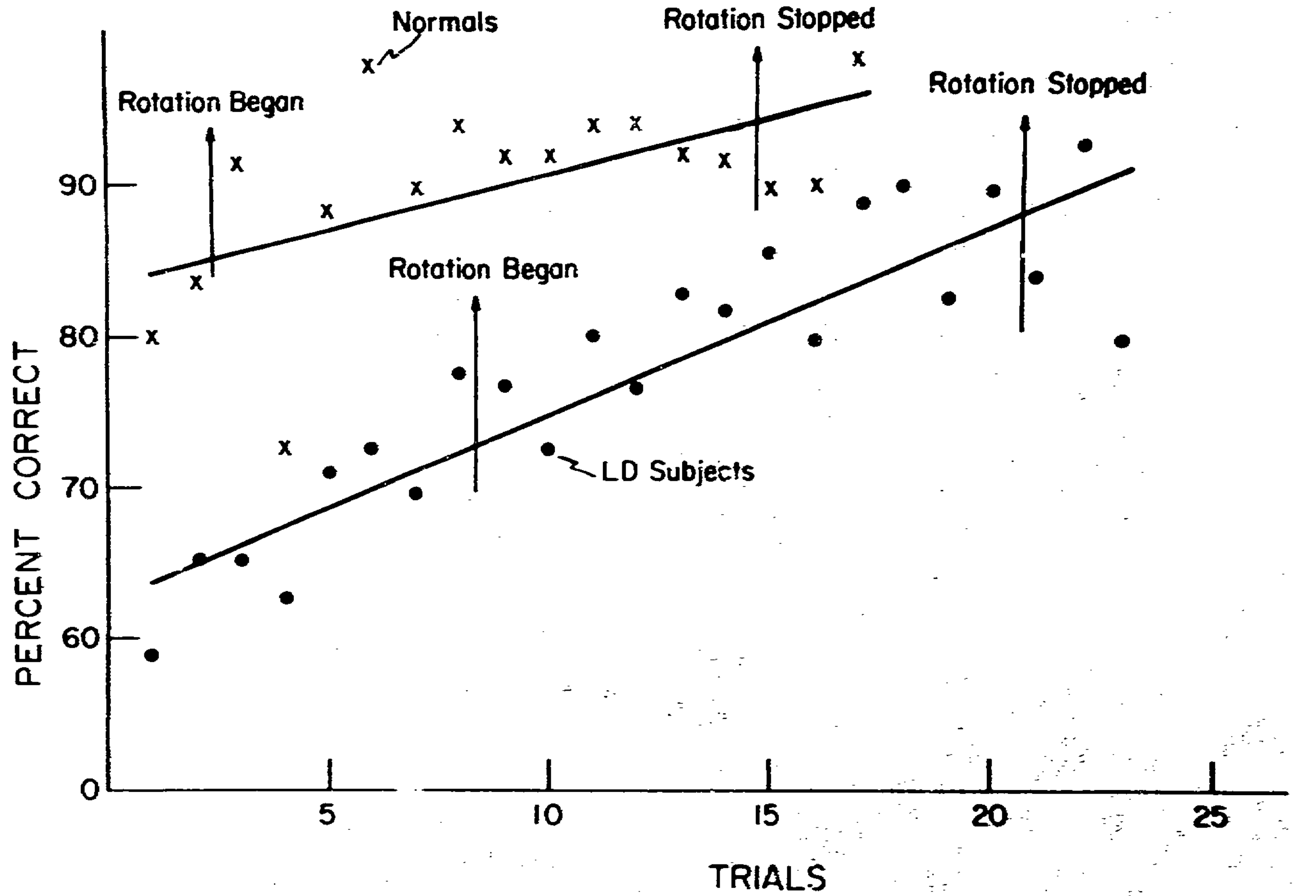


FIGURE 19. EFFECTS OF PRACTICE AND ROTATION AT 10 RPM ON THREE-CHANNEL VISUAL MONITORING FOR FOUR NORMAL SUBJECTS AND FOUR SUBJECTS WITH BILATERAL LABYRINTHINE DEFECTS

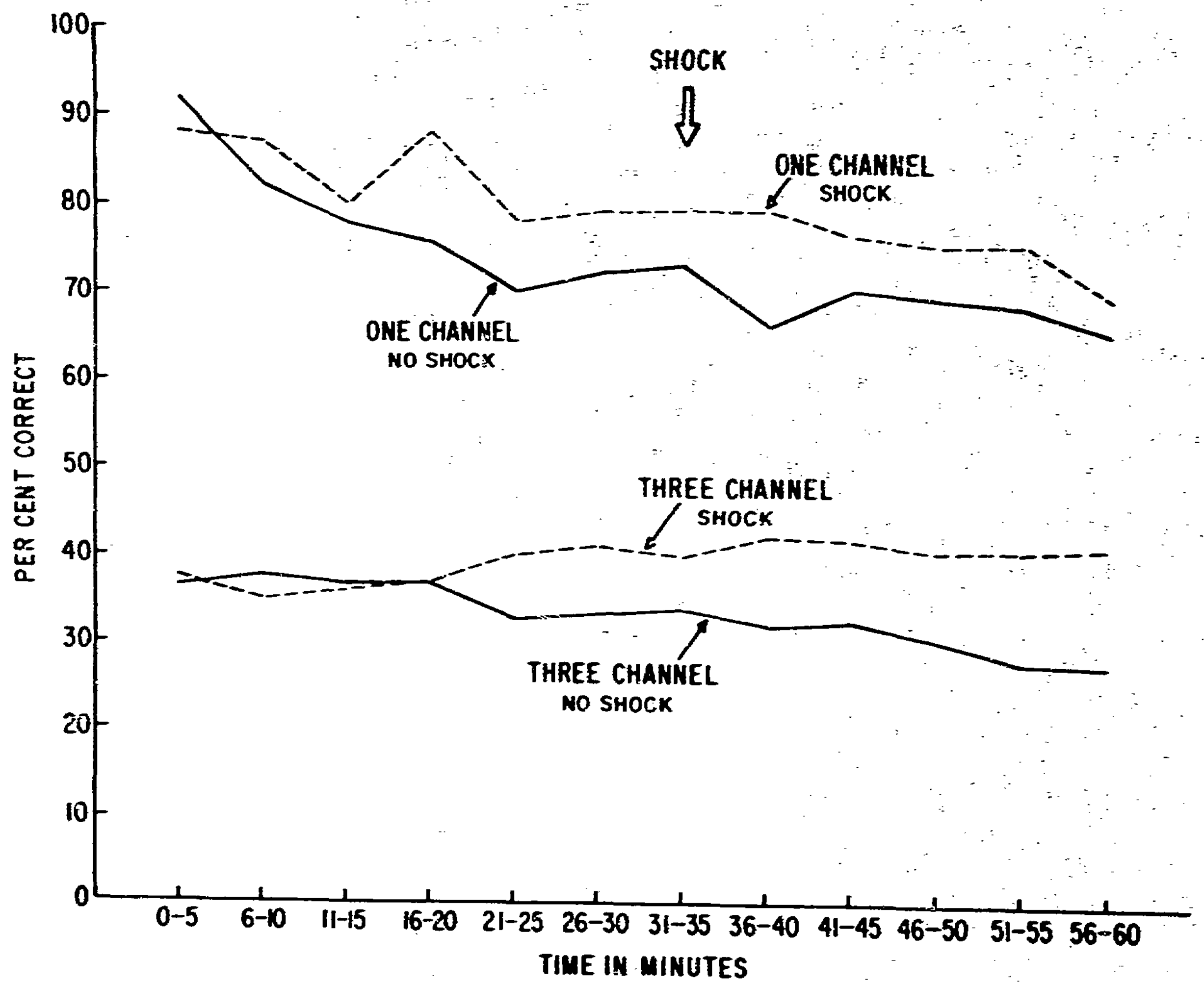


FIGURE 20. A COMPARISON OF ONE AND THREE-CHANNEL AUDITORY MONITORING DURING NORMAL AND STRESSED CON TIONS

which occasioned heavy turbulence. In general, most subjects experienced slight to moderate malaise, and some were frankly motionsick in the rougher flights.

Three-channel auditory performance measured early in a flight (i. e., while proceeding to the hurricane area) was used as a baseline for six subjects who alternated through all three aircraft. The pooled performance for six flights appear as Figure 21, and it may be seen that the magnitude of the decrement appears to be related to the turbulence.

7. It was reported elsewhere (Experiment I and II) that individual differences interacted with performance on the three- and one-channel auditory monitoring tasks. The principle finding being that an ability to do the task was correlated with the amount of decrement on the three-channel monitoring, but not the one-channel monitoring. In another experiment (Kennedy, in preparation), the same one-channel (N = 85), two-channel (N = 97), and three-channel (N = 91) testing was conducted as before with one exception: The subjects were instructed to respond to their assigned stimulus (one, two, or three-channels) by pressing at <u>every</u> occurrence, instead of <u>counting to</u> four before responding, as previously.

These results appear in Figure 22, along with the previous findings. As expected, overall performance was better on the simpler task. In addition, support was found for the notion described in Experiment III (Table 8) that an ability to do the three-channel task early in the session was negatively correlated ($P < .01$) with vigilance over the session (i. e., more decrement with high early scores). This same comparison was of opposite sign, but was

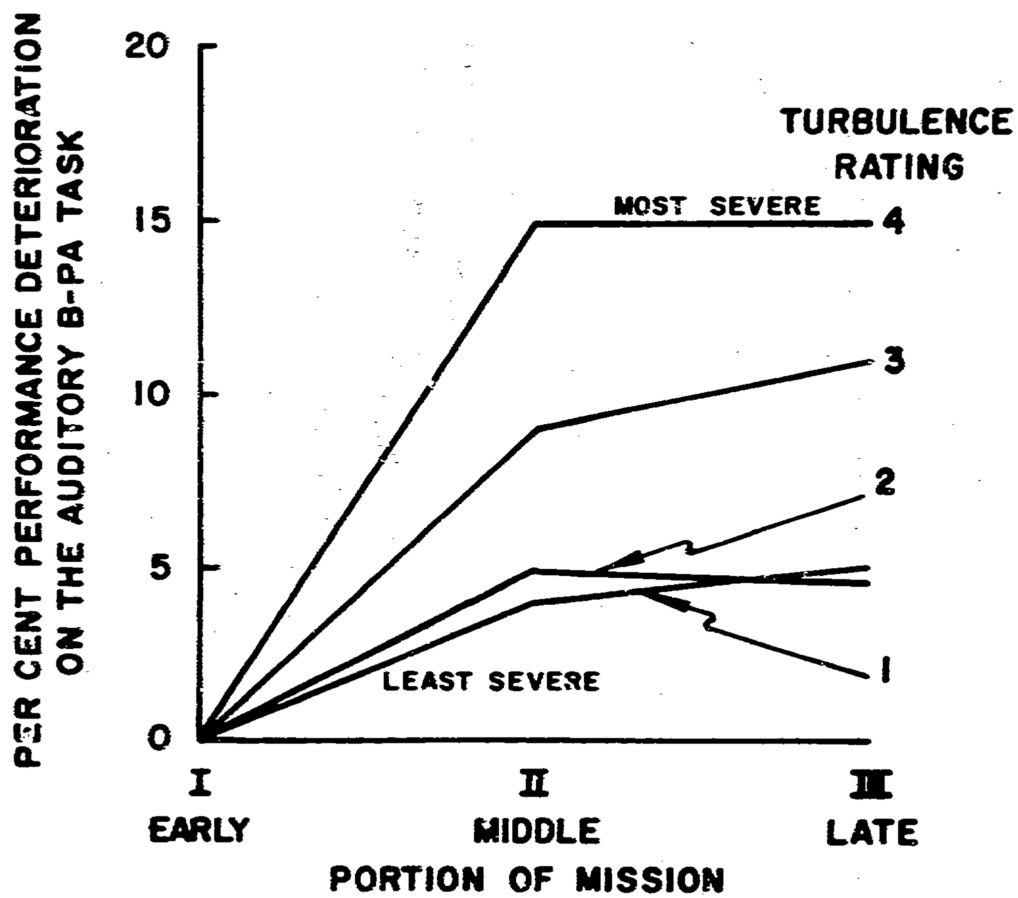


FIGURE 21. PERFORMANCE DETERIORATION IN AIRCRAFT ON THREE-CHANNEL AUDITORY MONITORING DURING FOUR HURRICANE PENETRATIONS OF DIFFERENT SEVERITY

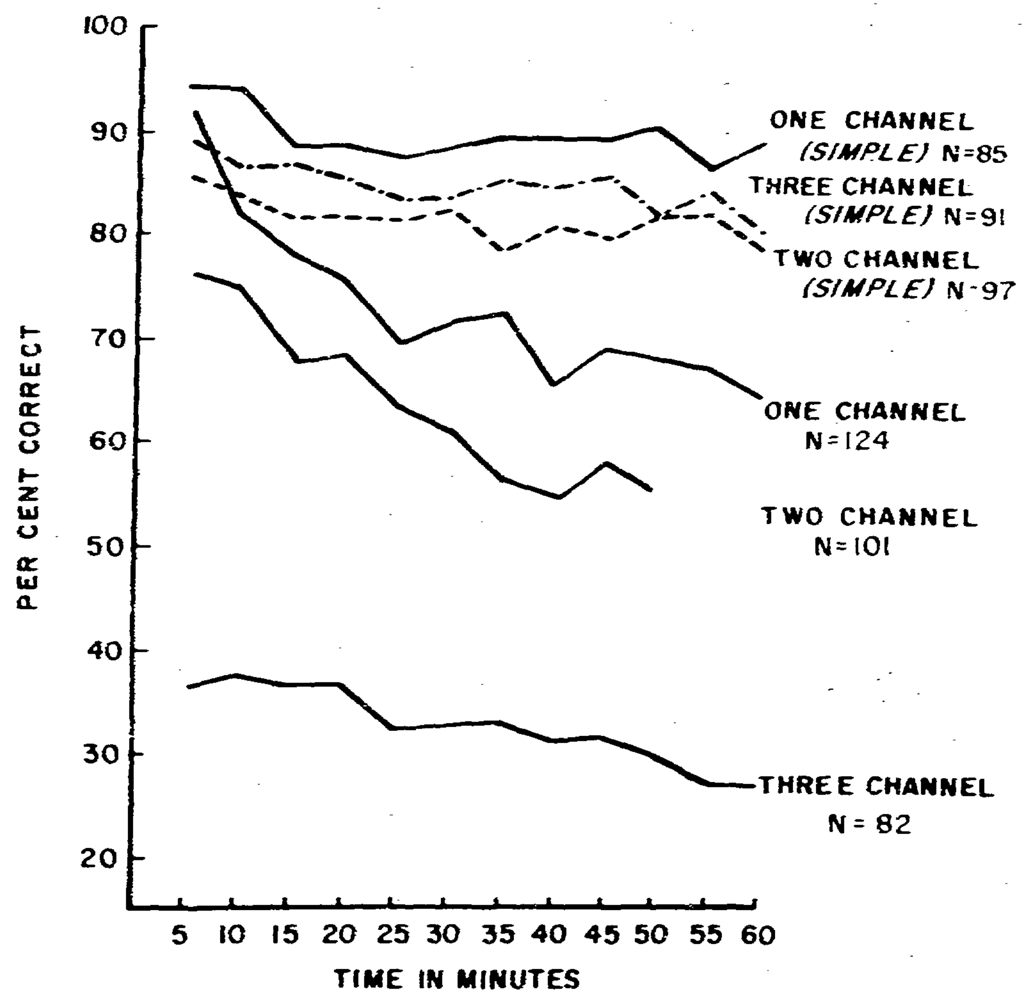


FIGURE 22. A COMPARISON OF PERFORMANCES ON SIX AUDITORY VIGILANCE TASKS

insignificant for one-channel performance ($P > .3$), and opposite and significant ($P < .01$) for two-channel monitoring (i.e., less decrement with high early scores).

The slight superiority of mean three-channel performance versus two-channel monitoring is most likely a scoring artifact, which is described more fully elsewhere (Kennedy, in preparation).

Summary and Conclusions

The available literature for a particular cognitive performance test has been reviewed. The original form of the test employed visual (lights) presentation, but recent studies have itilized auditory (tones) signals. The present form of the auditory version is a magnotic tape which can be presented on a standard tape recorder. (Filters can be used to initiate lights or vibrotactile signals if desired.) Laboratory norms on six different versions of this task for about 100 college graduate males (for each version) are available, as well as relationships to personality and other subject variables (e.g., hours sleep) for these persons. Some other attributes are: (a) practice effects appear small on the three-channel auditory version and are known for the three-channel visual version, (b) the test can be group-administered, (c) it is relatively simple and inexpensive to construct, (d) there are many possibilities for constructing alternate forms, (e) task difficulty can be controlled largely by instructions, (f) latency of response within broad limits (viz, a second or two) is generally not a factor and so the task can appropriately be used even when environmental variables can interact physically with response speed (e.g., underwater), (g) stimulus recording is binary and therefore mechanically simple. Further, the regularity of the stimuli makes scoring relatively easy and relatively independent of where on the magnetic tape a session begins, (h) proportion measures are essentially linear ($r > .95$) with absolute measures (viz, hits) and therefore direct comparisons can be made over different tasks, (i) unlike many other vigilance tasks, many signals and responses occur, and so individual time analyses

are possible, (j) a suggestion is present that performance on forms of this task may be age-related.

In conclusion, it is felt that this test and its variants represent a useful research tool for studying complex cognitive performance.

References

Buckner, D. N., & McGrath, J. J. (Eds.) Vigilance: A Symposium. New York: McGraw-Hill, 1963.

Graybiel, A., Kennedy, R. S., Knoblock, E. C., Mertz, W., Fregly, A. R., Colehour, J. K., & Miller, E. F. The comparative effects of 12 days rotation on four normal subjects and four persons with bilateral labyrinthine defects. Pensacola, Fla., Naval Aerospace Medical Research Laboratory, in preparation.

Guedry, F. E. Psychophysiological studies of vestibular function. In W. D. Neff (Ed.) Contributions to sensory physiology, Vol. 1. New York: Academic Press, 1965. Pp. 63-135.

Helper, M. M. The effects of noise on work output and physiological activation. Ft. Knox, Ky., U. S. Army Medical Research Laboratory, Report No. 270, 1956.

Jerison, H. J. Effect of a combination of noise and fatigue on a complex counting task. Wright-Patterson AFB, Ohio, WADC Technical Report 55-360, 1955.

Jerison, H. J. Differential effects of noise and fatigue on a complex counting task. Wright-Patterson AFB, Ohio, WADC Technical Report 55-359, 1956.

Kennedy, R. S. Unpublished observations, 1968.

Kennedy, R. S. A comparison of performance on visual and auditory monitoring tasks. Human Factors, 1971, 13, 93-97.

Kennedy, R. S. Individual differences on auditory vigilance tasks, in preparation.

Kennedy, R. S., & Coulter, X. The interactions between stress, vigilance and task complexity in flight personnel. Pensacola, Fla., Naval Aerospace Medical Institute, NAMI 1087, in press.

Kennedy, R. S., Moroney, W. F., Bale, R. M., Gregoire, H. G., & Smith, D. G. Comparitive motion sickness symptomatology and performance decrements occasioned by hurricane penetrations in C-121, C-130, and P-3 Navy Aircraft. Pensacola, Fla., Naval Aerospace Medical Institute, in press.

Mackworth, J. F. Vigilance and habituation: A neuropsychological approach. Baltimore: Penguin Books, 1970.

Moroney, W. F., & Kennedy, R. S. The effects of practice and distributed exposure on a complex auditory vigilance task. Pensacola, Fla., Naval Aerospace Medical Institute, in preparation. (a)

Moroney, W. F., & Kennedy, R. S. A comparison of auditory vigilance performance during group testing vs. when visually isolated or auditorily distracted. Pensacola, Fla., Naval Aerospace Medical Institute, in preparation. (b)

Wendt, G. R. Vestibular functions. In S. S. Stevens (Ed.) Handbook of experimental psychology. New York: Wiley, 1951, 1191-1223.

Appendix D

Subject's Pre-Experimentation Interview

and Title Page of Group Embedded Figure Test

SUBJECT'S PRE-EXPERIMENTATION INTERVIEW

Experiment_______________
Experimenter_____________
Subject__________________
Date_____________________

1. Have you been ill in the past week? Yes___ No___. If yes, specify:
   a) severity, b) time course, c) where localized, etc.

2. I am___ am not___ in my usual state of fitness.

3. Drugs:

   a. How much alcohol have you consumed during the past 24 hours?
      drinks___

   b. How many cigarettes in past 3 hours?___ cigars___ pipefuls___

   c. Have you taken any drugs or medications of any kind in the past 24 hours?
      Yes___ No___ If yes, were they

      1. Sedative or tranquilizer ____________________
      2. Analgesic (aspirin) ____________________
      3. Anti-motion sickness remedy (antihistamine)______ __________
      4. Other (specify) ____________________

4. How many hours sleep did you have last night?_______ Was this
   sufficient?____________ Insufficient?_________

5. How concerned are you regarding your performance on this test?
   None___ Minimal___ Moderate___ Great___ Very great___

6. Do you expect to perform better___ less well___ same___ as average person?

7. Food:

   a. How many hours since your last meal?___

   b. Approximately how many cups of fluid have you had in the past 2 hours?
      ____ ______

Name: ____________________

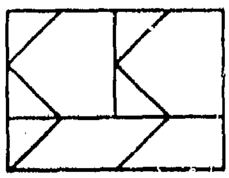
HIDDEN FIGURES TEST — Cf-1

This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered A, B, C, D, and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

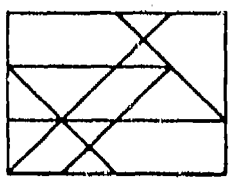
NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

Now try these 2 examples.

A B C D E

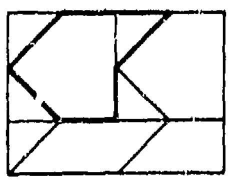
I 

A B C D E

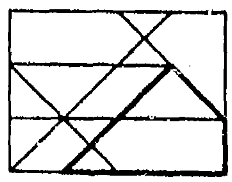
II 

A B C D E

The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

I 

~~A~~ B C D E

II 

A B C ~~D~~ E

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 10 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Developed under NIMH Contract M-4186

Appendix E

Reliability and Consensual Validity of a Method for Scoring Habituation of Nystagmus

Introduction

The form of the vestibular eye movement response in man has been described by Wendt (1936, 1950, 1965). When sinusoidal oscillation is the stimulus, the angular velocity of the eye is proportional to the stimulus, and "...over the bandwidth 0.017 to 17 Hz [1.02 - 1020 cycles/minute] the semicircular canals act like integrating accelerometers and the neural discharge to the central nervous system is a frequency-coded analogue of head velocity" (Robinson, 1968, p. 1041). The general nystagmoid eye movements include a slow compensatory eye deviation away from the direction of the acceleration, followed rapidly by a quick flick of the eye opposite in direction to the slow movement, called slow and fast phase, respectively. Wendt (1936, p. 316-317), using 0.33 cps as an oscillation stimulus, has shown that the slow phase eye movement "... is hardly distinguishable from the sine function" of the stimulus, being ".1 later on the eye movement curve" where acceleration changes to deceleration, and being within (plus or minus) .07 second where the direction of stimulus movement changes. While the amplitude of the eye movement is about 20% less than the stimulus, Niven, Hixson & Correia (1965) have reported that over a range of sinusoidal oscillation frequencies (12 - 24 cpm) a transfer function between instantaneous eye velocity and angular acceleration exists. In their study, they report "...that the natural frequency is in the range 0.2-0.4 cps [12-24 cpm] for three of their six subjects" (p. 48), and lower frequencies (i.e., longer periods, e.g. ten seconds) of sinusoidal oscillation result in eye movement velocities which are somewhat in advance of the velocity of the

stimulus. These results agree with those of Wendt (1936) and show that within this range (0.2 - 0.4 cps) for the accelerations and displacements employed, the peak velocity of the eyes and zero velocity of the eyes coincide with the peak and zero velocities of the stimulus, respectively. Young (1968) feels that the torsion pendulum model of Steinhausen (1931, cited in Young, 1968) generally describes the action of the cupula, whereby in response to a sinusoidal forcing function the cupula deviation is in phase with acceleration at low frequencies, in phase with velocity at the natural frequencies (e.g., 12-24 cpm) and can lag velocity by as much as 90° at very high frequencies.

Figure 23 is an example of an eye movement record obtained from a subject who was oscillated 75° left and right 12 times per minute (i.e., 0.2 cps). In the upper portion of this figure, it may be seen that the slow phase of the eye movement's velocity coincides with the stimulus, with respect to the points where both are zero and maximum. Presumably, records like these are obtained when the subject is alert (Wendt, 1965). Under light barbiturate anesthesia, however, Wolfe (1966) and Melville Jones (1971) have shown that in cat, certain characteristics of the eye movement change, and Wendt (1965) has records in unalert humans which resemble those of anesthetized cats. A similar record from the present study is shown in the lower portion of Figure 23.

One important aspect of the eye movements obtained in non-alert or anesthetized subjects appears to be an absence of fast phases, although characteristics of the slow phase still seem to remain. Some investigators (Collins,

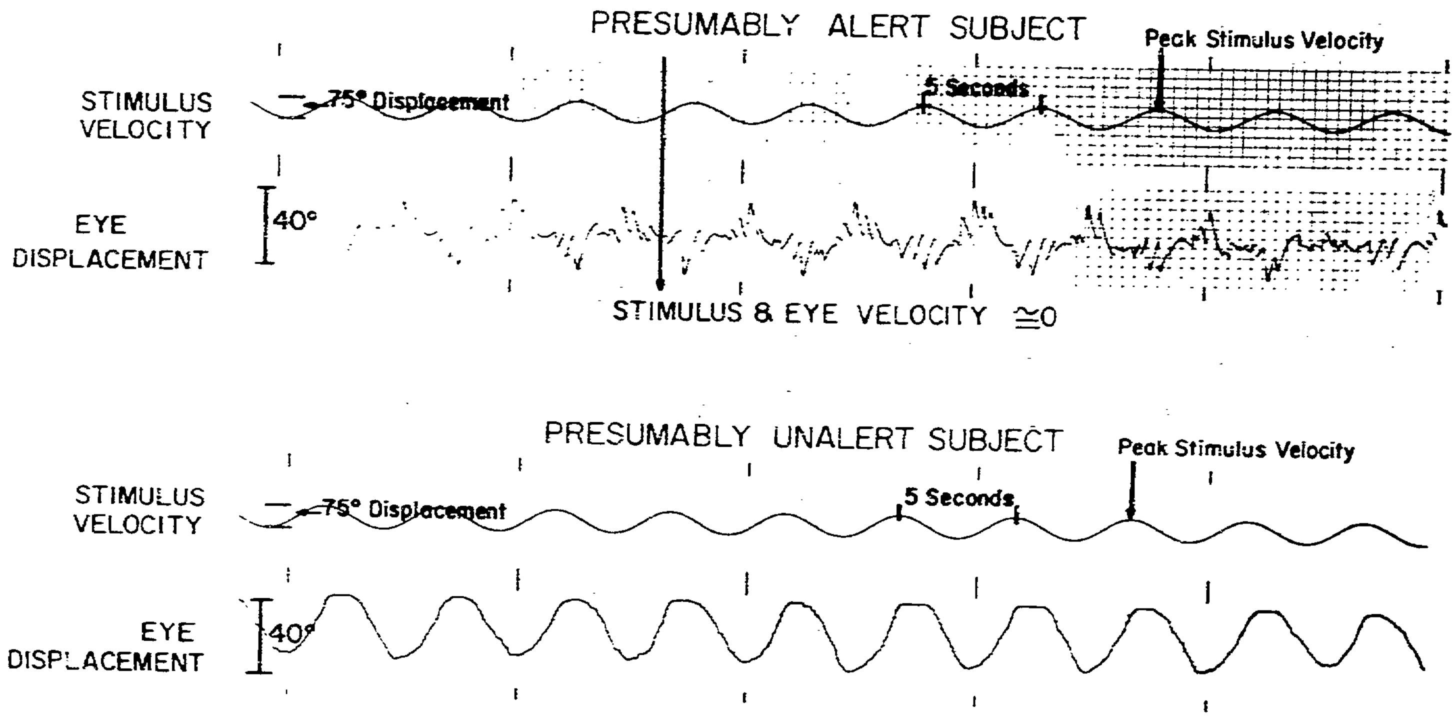


FIGURE 23. EYE MOVEMENTS DURING SINUSOIDAL OSCILLATION FOR AN ALERTED AND UNALERTED SUBJECT

1964; Guedry, 1965; Guedry & Graybiel, 1961; Wendt, 1965) report other changes in eye movement during repeated vestibular stimulation which are considered habituation. Wendt (1965), for example, shows (p. 137, Figures 8, 9 and 10) "habituated" records where with sinusoidal oscillation (30°, .33 cps) fast phases are so frequent and so large that the eye movement response is almost the exact opposite of what is seen in the lower portion of Figure 23. Records like those of Wendt (1965) were not obtained in the present study, and the larger arcs (75°) employed here may be a reason for the failure to find these types of responses. Other types of eye movements (disconjugate, wandering, or none) are also obtained.

Furthermore, in some vestibular studies where "habituation" occurs, it appears that the form of the response which qualifies for the term "habituation" may be peculiar to the stimulus profile. For example, qualitatively different responses are obtained following long term Coriolis stimulation (Guedry & Graybiel, 1961) where eye movement responses compensatory to those which occurred during the period of Coriolis stimulation occur in some persons who have adapted to the stimulus after the latter is stopped. This finding can be contrasted with the results from responses to accelerations (positive or negative) which are not followed immediately by another acceleration (Brown, 1965; Brown & Crampton, 1965; Guedry, 1965), where "habituation" is reflected in the relative absence of eye movements. Yet all of the above have been termed "habituation" (see for example Collins, 1964, p. 29 ff; Guedry, 1965, p. 100 ff; Wendt, 1964, p. 1000 ff).

It appears that the major changes in the form of the eye movement response to be expected in connection with sinusoidal oscillation are disappearance of the fast phase, overabundance of fast phase, disconjugate, wandering or no eye movements.

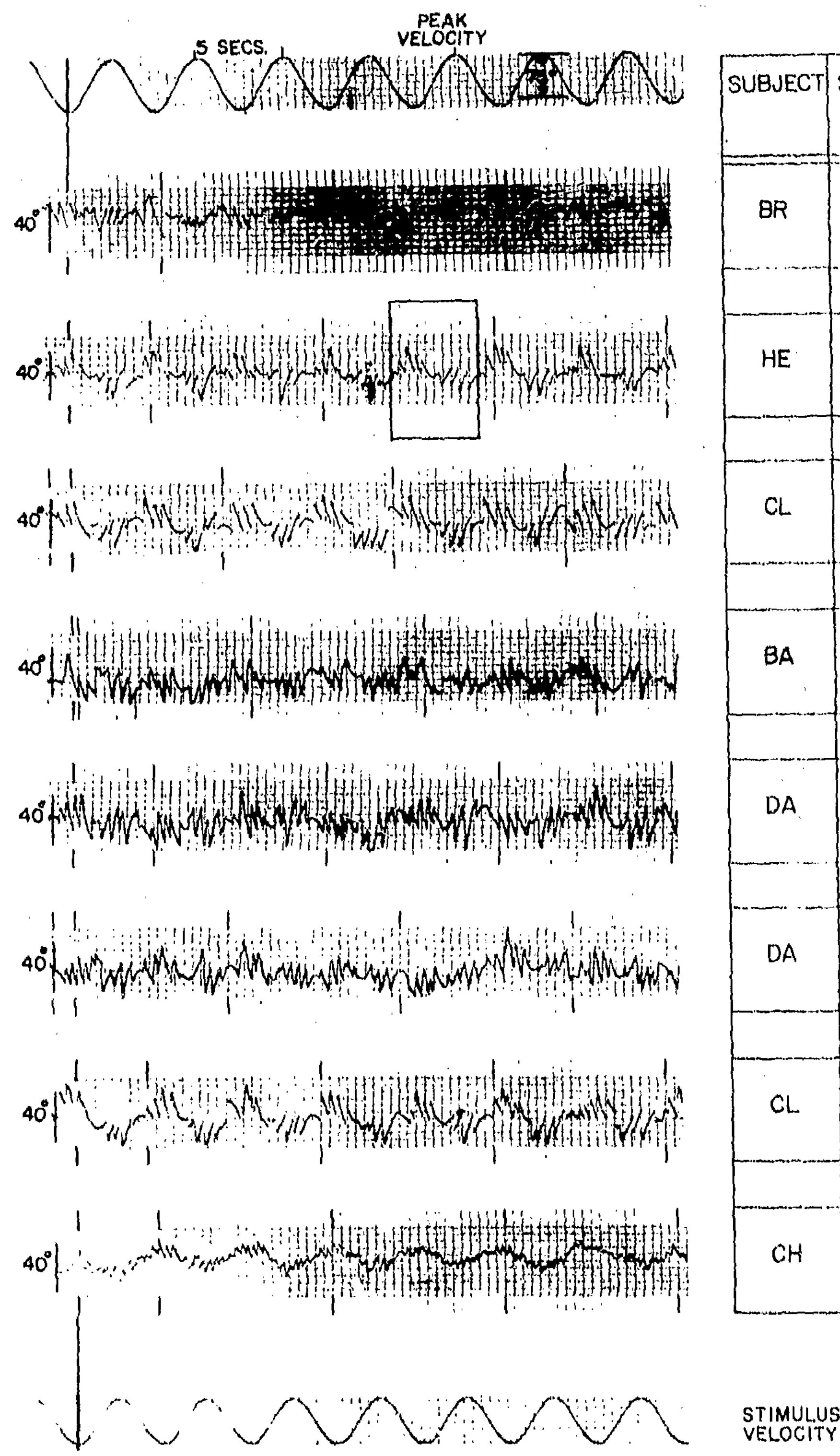
For reasons stated in Experiment I, it was felt that certain characteristics of vestibular eye movements might provide a useful measure of arousal. In order to test this hypothesis in Experiment I, a reliable method for scoring nystagmus eye movements was required. The purpose of the present study was to develop by visual inspection a reliable method for scoring nystagmus eye movements which resulted from sustained sinusoidal oscillation.

Method

After dark adapting for 20 minutes (Appendix B), 50 subjects were oscillated for 30 - 50 minutes at 12 cpm (.2 cps) with a 75° displacement at a 47°/sec peak velocity. Several factors dictated the use of these particular stimulus values (cf page 15). However, a range of oscillation profiles (.05 - .4 cps, 25°-150° displacement) in several subjects also were employed to provide the author (RK) with wider experiences in the types and ranges of responses to be expected. No attempts were made to assign values to any of the responses until after a number of complete (30-50 minute) records, obtained with different sinusoidal stimuli, in different subjects, were reviewed. Then, a three-point scale of the presence of nystagmus[1] was used (100%, 50%, 0%) to rate eye movements within <u>each</u> sinusoidal cycle. It soon became apparent that the rater (RK) preferred finer gradations. Records like those shown in the upper part of Figure 23 were considered 100 (i.e., 100%) and a ten-point scale (100, 90, 80, 70, etc.) was then employed to reflect proportionately lesser amounts of nystagmus. In addition, because of an observed difference between "complete" and almost "complete" absence of nystagmus, two additional lower numbers (1 and 5, respectively) were employed. Responses like those in the bottom of Figure 23 were scored "1".

Figures 24, 25, 26, 27 and 28 provide examples of each of the different numerical values which were assigned. The scores for each section (approximately one minute) of a subject's record shown in Figures 24 - 28 are the

[1]Nystagmus presence is the reciprocal of "habituation" in this study.



SUBJECT	SCORE	MINUTE WITHIN SESSION
BR	100	1
HE	100	2
CL	100	11
BA	100	29
DA	100	2
DA	100	12
CL	95	13
CH	95	14

FIGURE 24. EXAMPLES OF NYSTAGMUS RATED 95-100

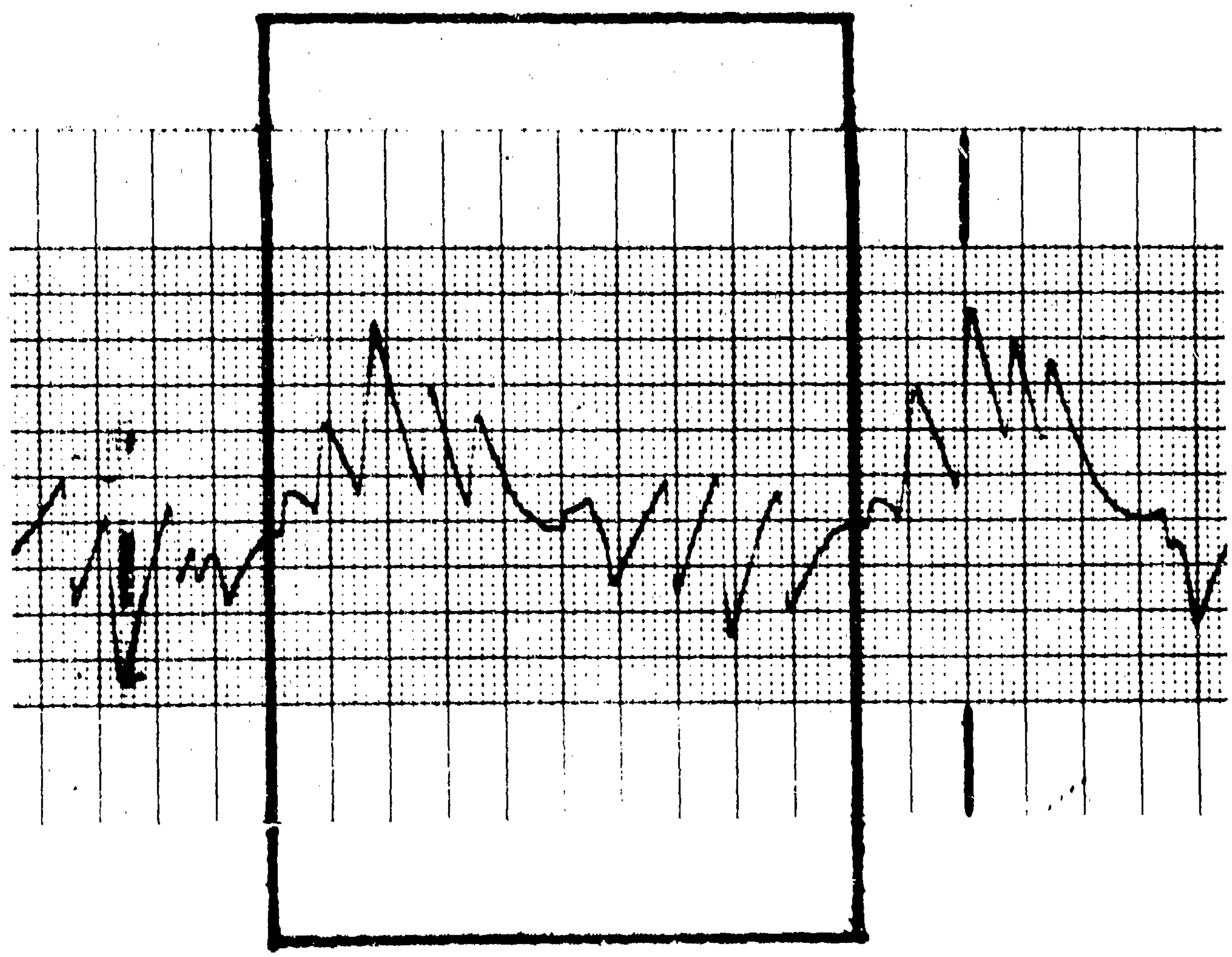
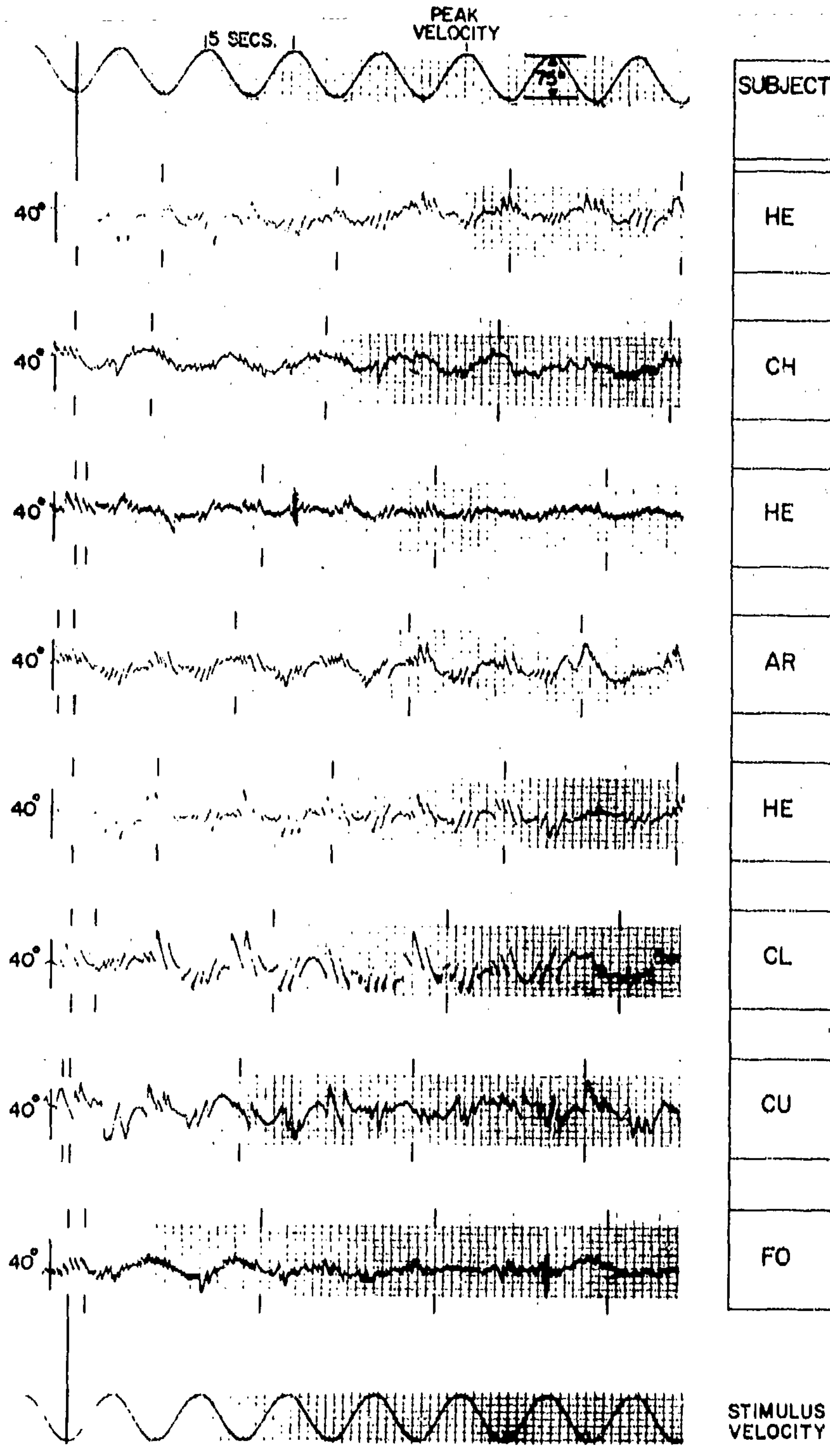
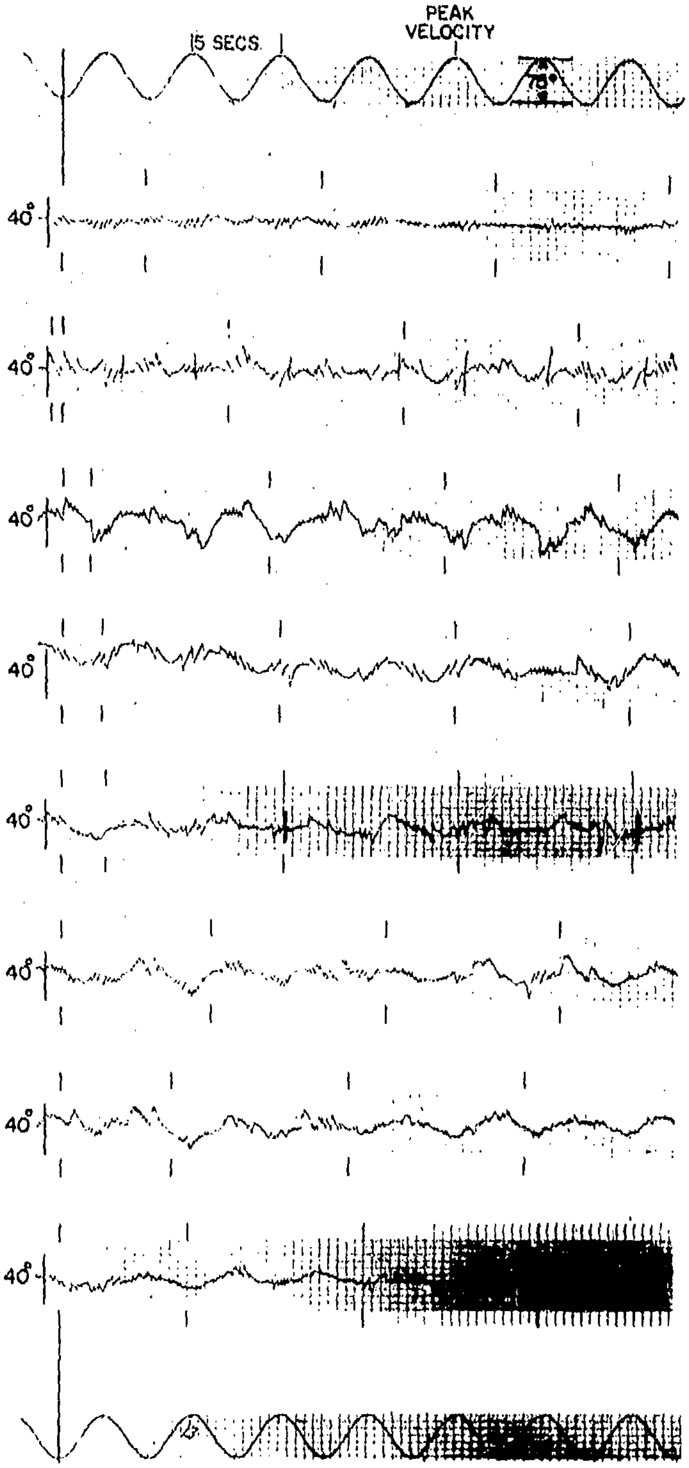


FIGURE 24a ENLARGED SECTION OF SUBJECT HE



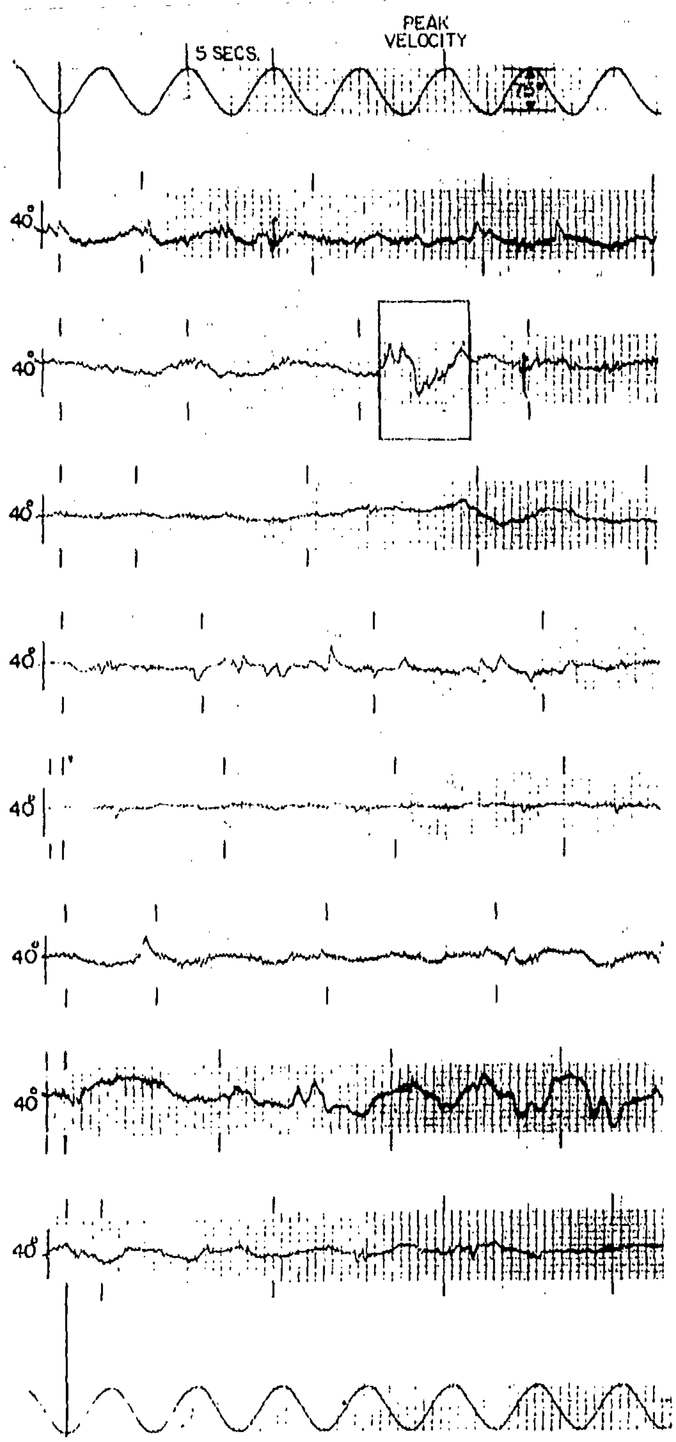
SUBJECT	SCORE	MINUTE WITHIN SESSION
HE	95	5
CH	90	19
HE	90	6
AR	90	5
HE	90	4
CL	90	24
CU	90	14
FO	80	19

FIGURE 25 EXAMPLES OF NYSTAGMUS RATED 80 - 95



SUBJECT	SCORE	MINUTE WITHIN SESSION
CA	80	3
ST	80	17
GR	80	3
CA	80	30
DN	70	13
AR	70	8
AR	60	2
DN	60	16

FIGURE 26. EXAMPLES OF NYSTAGMUS RATED 60-80



SUBJECT	SCORE	MINUTE WITHIN SESSION
WE	50	3
SH	50	2
SH	40	7
EV	40	7
CO	40	5
WE	30	5
DE	30	6
DN	20	29

FIGURE 27. EXAMPLES OF NYSTAGMUS RATED 20-50

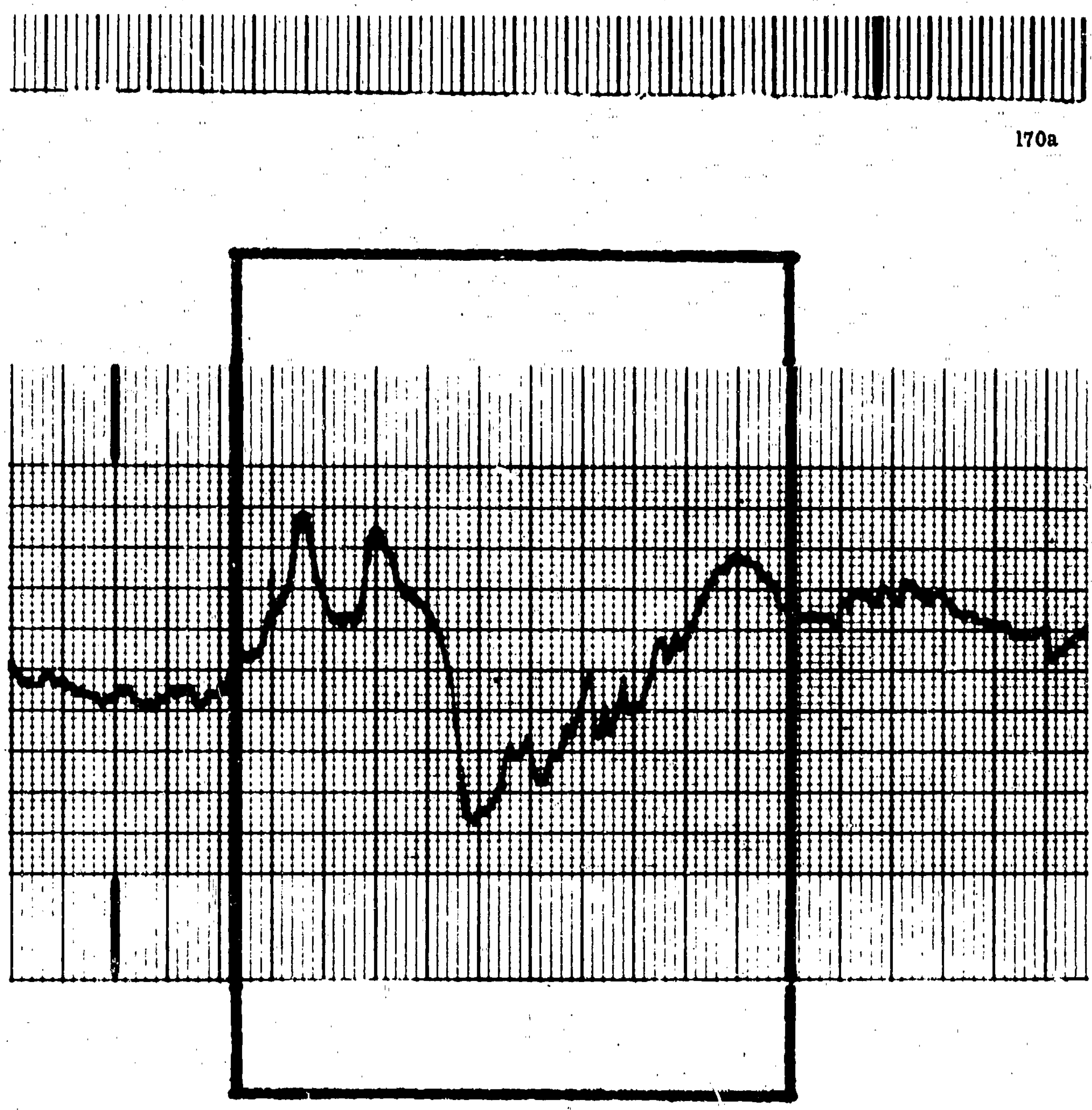
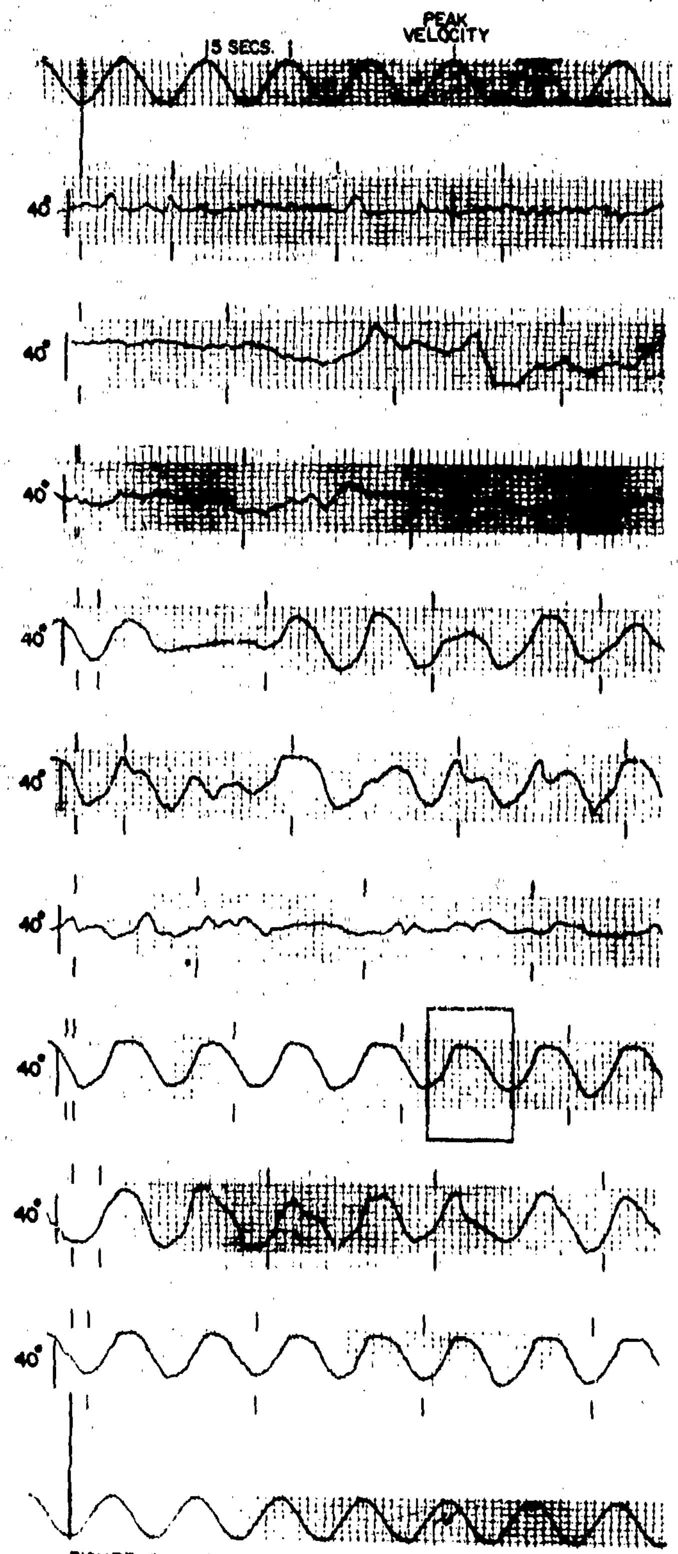


FIGURE 27a ENLARGED SECTION OF SUBJECT SH



SUBJECT	SCORE	MINUTE WITHIN SESSION
HE	20	24
BR	10	41
WE	10	24
EM	5	42
MC	5	14
EV	5	24
DU	1	18
EM	1	42
DU	1	22

FIGURE 28. EXAMPLES OF NYSTAGMUS RATED 1-20

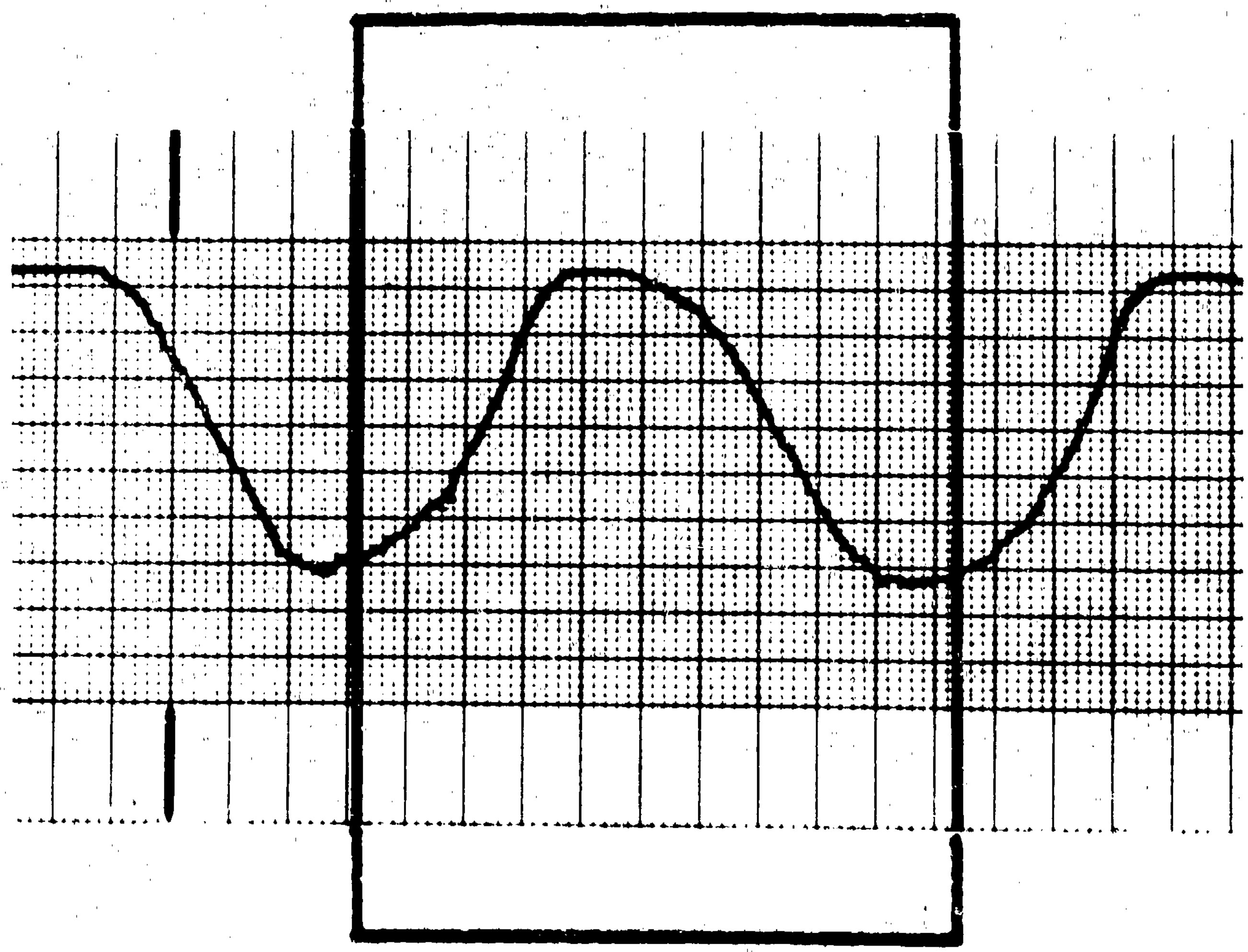


FIGURE 28a ENLARGED SECTION OF SUBJECT DU

average for that section, although each cycle was rated separately when an actual record was scored[2]. The chief criteria used in scoring were both the quality and the quantity of the fast phases which were present. If an entire cycle (i.e., 100%) was occupied with brisk fast phases and strong, pronounced changes in the appropriate direction, then the response was rated 100 (see Figures 24 and 25). Departures from this received relatively lower ratings (Figures 26, 27 and 28). A template was fashioned of the sinusoidal stimulus to aid in checking on the appropriateness of the direction of eye movements. This template fitted the stimulus velocity record, and when superposed on eye movement records, permitted easy recognition of the expected direction the eye should be moving at any point within a cycle. A quick flick of the eyes which did not follow a slow phase and which went in an inappropriate direction was not classed as a fast phase.

A cycle was rated "1" if absolutely no fast phases were present (and if the slow phase was intact), and "5" if their absence was almost certain (and/or the slow phase was not intact)[3]. If 50% of a cycle contained good nystagmus, it was rated 50 (Figures 26 and 27). Efforts were made not to be influenced in the scoring by occasional changes in amplitude or differences in gain between subjects. An entire record was reviewed before scores per cycle were assigned.

---

[2]Enlargements of portions (one cycle) of Figures 24, 27 and 28 appear as Figures 24a, 27a, and 28a, respectively.

[3]This would give slightly greater weight to systematic eye movements without fast phases as compared to wandering eye movement periods which also occurred. This was considered justified, since it was felt the former indicated greater loss of arousal.

For practice, some records were scored upside down and backwards, and some were scored at half the gain.

Other factors used in scoring were: (a) Generally, the more beats present (i.e., a fast phase following an appropriate slow phase), the higher the rating; (b) generally, the greater the area of a cycle covered by nystagmus, the higher the score; (c) the more brisk the fast phase, the higher the rating; (d) responses (fast or slow) which bore no systematic relationship[4] to the stimulus were not considered nystagmus and received lower ratings (Figure 28).

The records were scored directly by assigning a value to each five-second cycle of nystagmus on separate paper. No marks other than time appeared on the records. There were 12 scores (cycles) per minute, and the average score per minute was used in analyses. Most records were 50 minutes long.

Consensual validity. The only author who has attempted to deal systematically with scoring alertness by habituation to sinusoidal oscillation (Wendt, 1965) was consulted regarding scoring procedures. He (GRW) and his staff independently scored nystagmus records.

Reliability between scores. After the present author (RK) settled on his method of scoring, he trained one person (GA) for about 16 hours in his approach. The records scored by GA were compared to those scored by RK to determine the reliability of the criteria used by RK, and were also compared to a record scored by GRW. After this, another rater (BL) was trained by RK (also for about 16 hours), and their (RK vs. BL) scorings were then

[4] As determined by the template.

compared for reliability. Then BL instructed DU, GI, and HBM. The latter was a team of three man who scored records by committee, although all three did not always remain present for a complete scoring of a particular record.

In summary, GRW trained RK; RK trained GA and BL; BL trained DU, GI, and HBM. All scorers (other than GRW and RK) were naive regarding vestibular functions and the oculomotor system. They were military officers in flight training and, with the exception of GA (who was in the Marine Corps and had majored in plant biology), had majored in the natural sciences at the U. S. Naval Academy.

Internal reliability. The scoring of a 50-minute record for a subject was a lengthy process since 12 determinations were made for each minute of record (N = 600). To determine the agreement which could be obtained by sampling only portions of a record versus scoring an entire record, one-minute scores were obtained during the middle of each five-minute segment of a 50-minute session, and were compared with the full five minutes. Thus, mean scores for 2.5-3.5; 7.5-8.5; 12.5-13.5 minutes etc., were compared with mean scores for 0-5, 5-10, 10-15 minutes etc., for several subjects' records.

Results

Table 15 shows correlations between scores for one 18-minute record scored by GRW, RK, and GA. The comparison of GRW and RK is also shown in Figure 29. Although the methods employed in scoring are slightly different (GRW uses number of mm/minute without nystagmus, rather than a rating per cycle), correlations this high suggest that essentially the same things are being evaluated, particularly since all three scorers utilized their highest and lowest categories. In addition, 158 one-minute samples considered difficult to score by both raters (GRW and RK) were compared. These samples were separated from the rest of the record and, when scored out of context and in the absence of calibration marks, resulted in a correlation of .922 between GRW and RK.

Figure 30 shows a comparison of two scorings of a subject oscillated for 30 minutes who was alerted (by voice communication) on two occasions. Figure 31 shows another subject who was exposed to sustained sinusoidal oscillation on two occasions, once while monitoring auditory signals (with vigilance), and once while no control of mental activity was applied. In both Figures 30 and 31, the scores by both raters (RK and GA) were in general agreement. While the absence of mental work appeared to enhance a drop in the amount of nystagmus present, conversely, the direction of the subject's attention produced more nystagmus (cf Experiment I, Part 1).

Table 16 presents correlations of each of the raters (GA, BL, GI, DU and HMB) with RK. All correlations were high ($r > .90$), and when averaged (after

TABLE 15

Intercorrelations of Three Scorers of Vestibular Nystagmus

	GRW	RK	GA
GRW		.981	.967
RK			.985
GA			

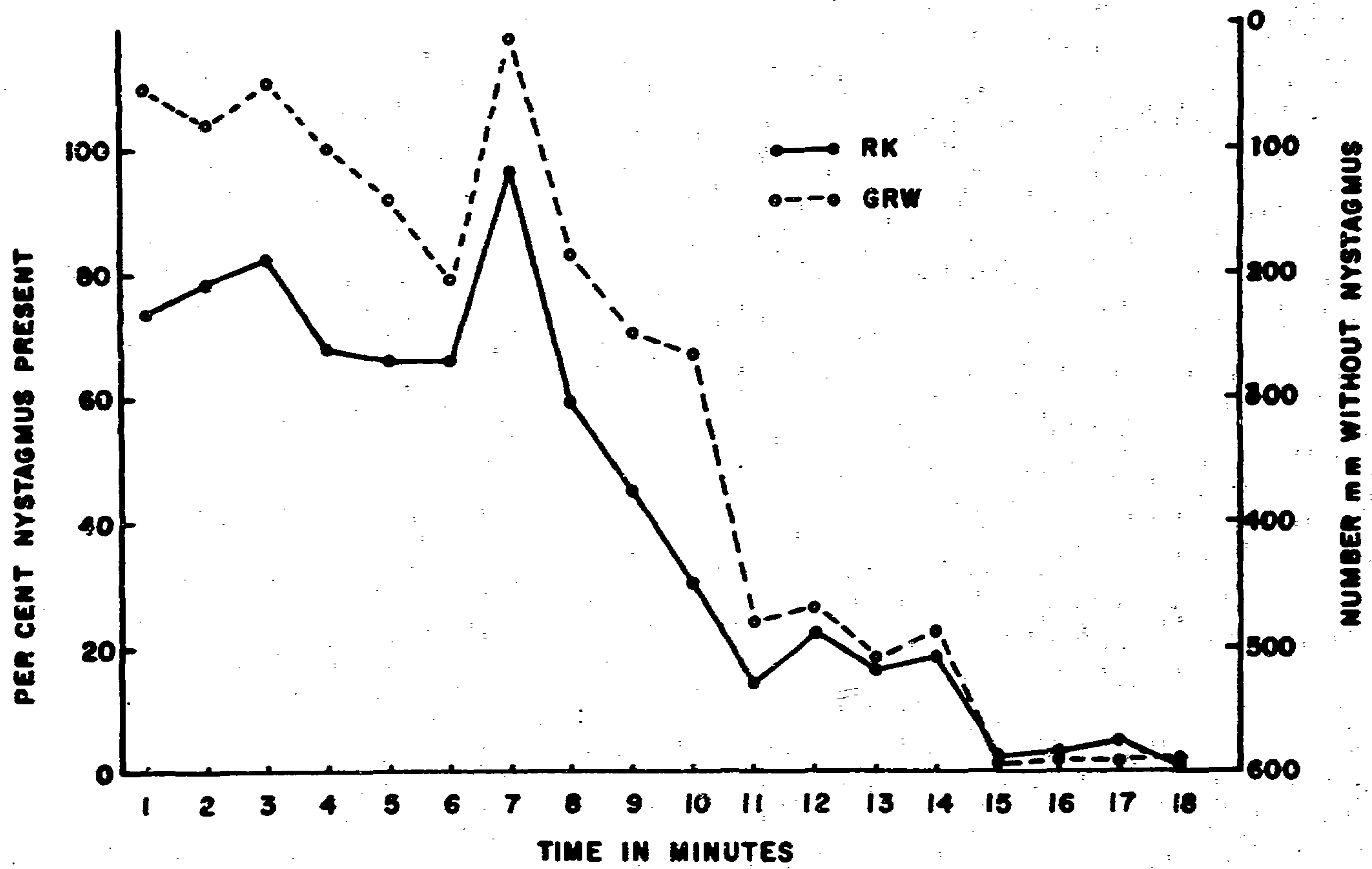


FIGURE 29. CORRESPONDENCE BETWEEN RK (AVERAGE RATING/CYCLE) AND GRW (mm/MIN WITHOUT "GOOD" NYSTAGMUS) FOR ONE SUBJECT

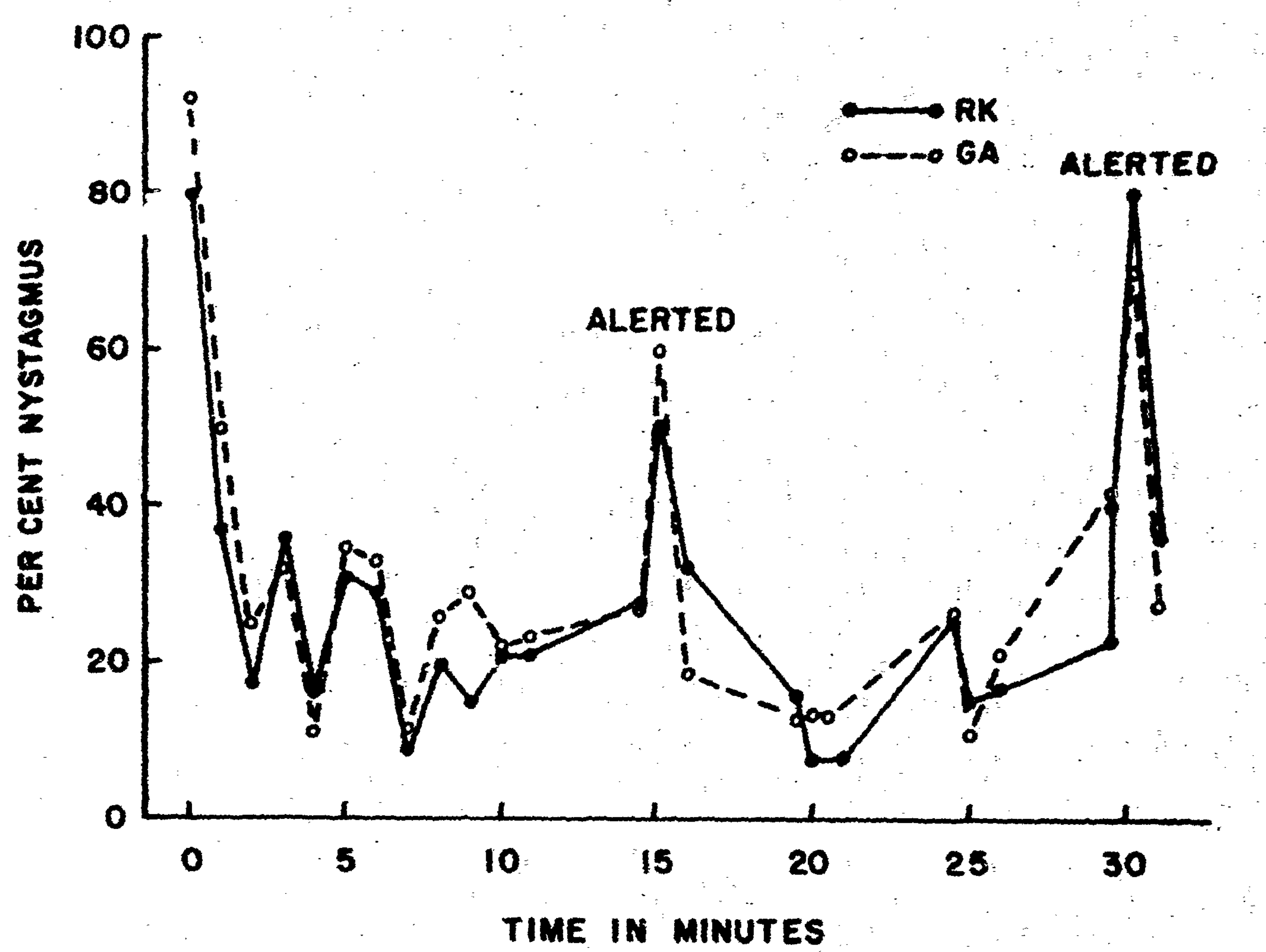


FIGURE 30. A COMPARISON OF TWO RATERS OF VESTIBULAR NYSTAGMUS, SUBJECTS ALERTED AT 15 AND 30 MINUTES

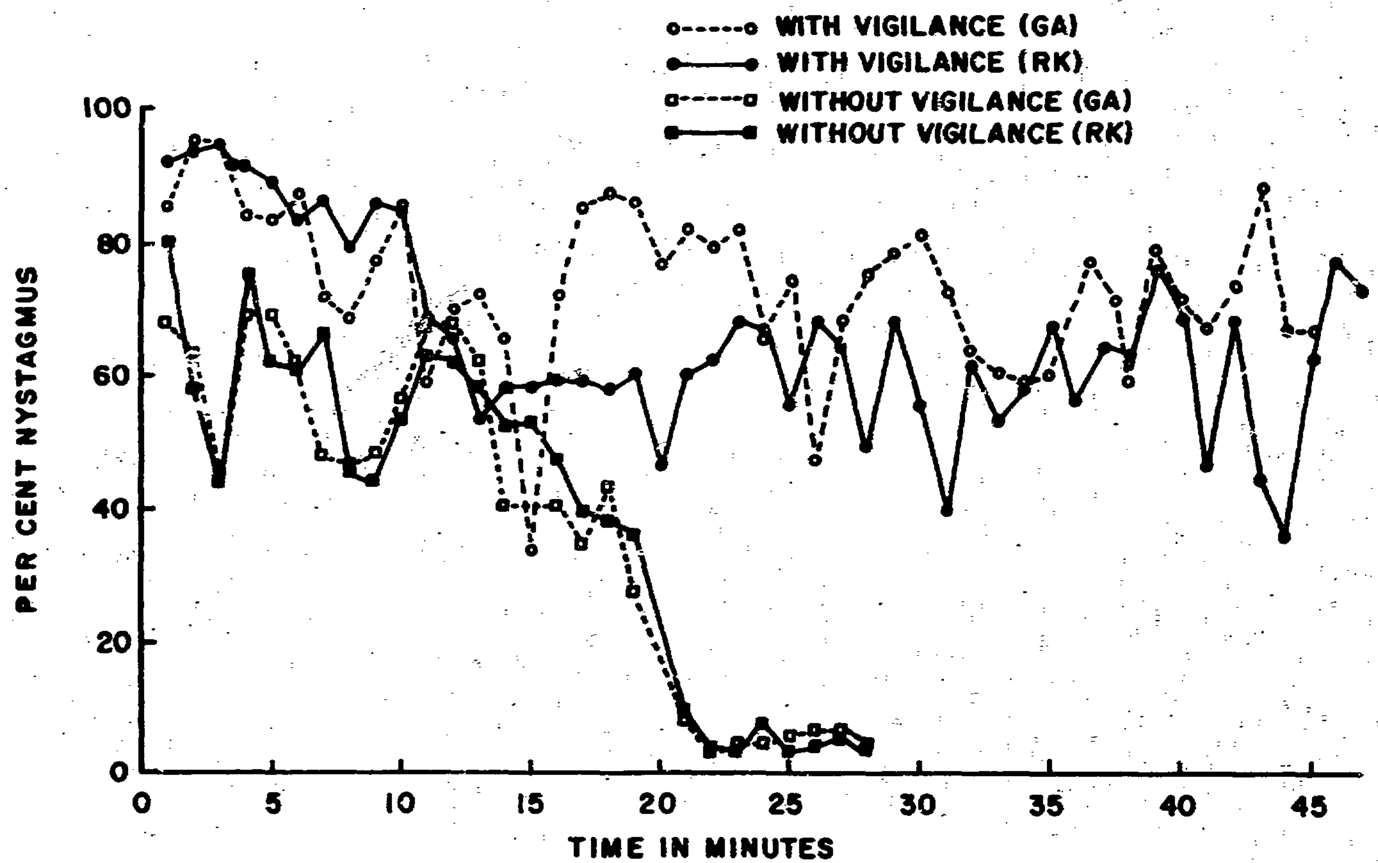


FIGURE 31. A COMPARISON OF SCORING ASSIGNMENTS OF TWO RATERS FOR A SUBJECT TESTED ON TWO OCCASIONS: WITH AND WITHOUT CONTROL OF MENTAL STATE BY AN AUDITORY VIGILANCE TEST

TABLE 16

Correlations of Individual Scorers with RK

	GA	BL	DU	GI	HMB
RK	.979	.939	.913	.902	.972
	.984	.995	.996	.956	.976
	.948	.962	.917	.902	.971
	.965	.934			.972
		.950			.906
r mean	.967	.965	.984	.917	.958

TABLE 17

Intercorrelations of Scoring by Different Raters

	DU	GI	HMB
BL	.981	.995	.940
	.942	.797	.967
	.958		.896
	.944		.423
	.954		.946
DU		.833	.892
			.941
			.832
GI			.854
			.953
			.922
			.731
			.929
HMB			

Fisher's Transformation) provide a mean correlation of $r = .965$. There was a suggestion that the reliability of GI was lower than the others[5].

Table 17 presents the correlations of the scores by the persons trained by BL (DU, GI and HMB) with his own scores. These correlations are generally high (i.e., $r > .90$) with one main exception: The latter a correlation of $r = .423$ by HMB with BL. The raw data for this comparison are pictorially presented in Figure 32. It may be seen that very little change in nystagmus ratings occurred over time for this subject. Although the largest difference in scores between the two raters was 12 units, and usually far less, the low variability of this subject over time may have occasioned the poor reliability between scorers. Moreover, slope scores or proportion of the decrement scores calculated by either rater to determine how nystagmus changed over time (i.e., habituation) for this subject would not be very different.

Figure 33 shows the correspondence between two methods of scoring: (a) The method described previously and (b) average number of appropriate compensatory fast phase beats per cycle. Although different scaled values were used (compare left and right ordinates), the relationship appears linear and the concordance is good.

Correlations for ten records not used in any of the previous analyses were calculated between a one-minute sample (each five minutes of oscillation) vs. the full five minutes, for 50 minutes. These correlations ranged from $r = .931$ to $r = .975$, and averaged (after Fisher's Transformation) $r = .960$. The

[5]Fortuitously, rather than by design, GI scored very few records.

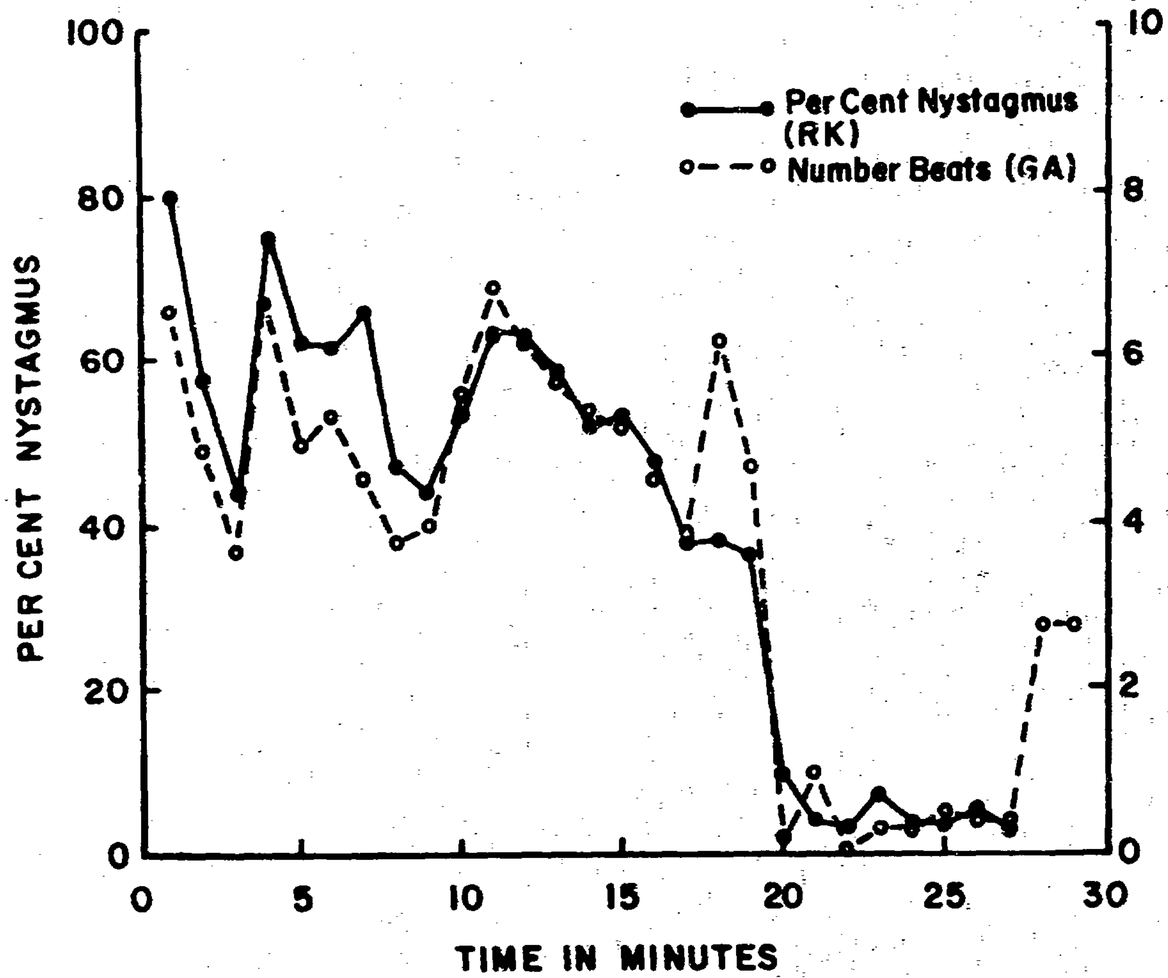


FIGURE 32. A COMPARISON OF TWO RATERS USING TWO DIFFERENT METHODS OF SCORING: RK-QUALITY OF NYSTAGMUS; GA-NUMBER OF BEATS/CYCLE

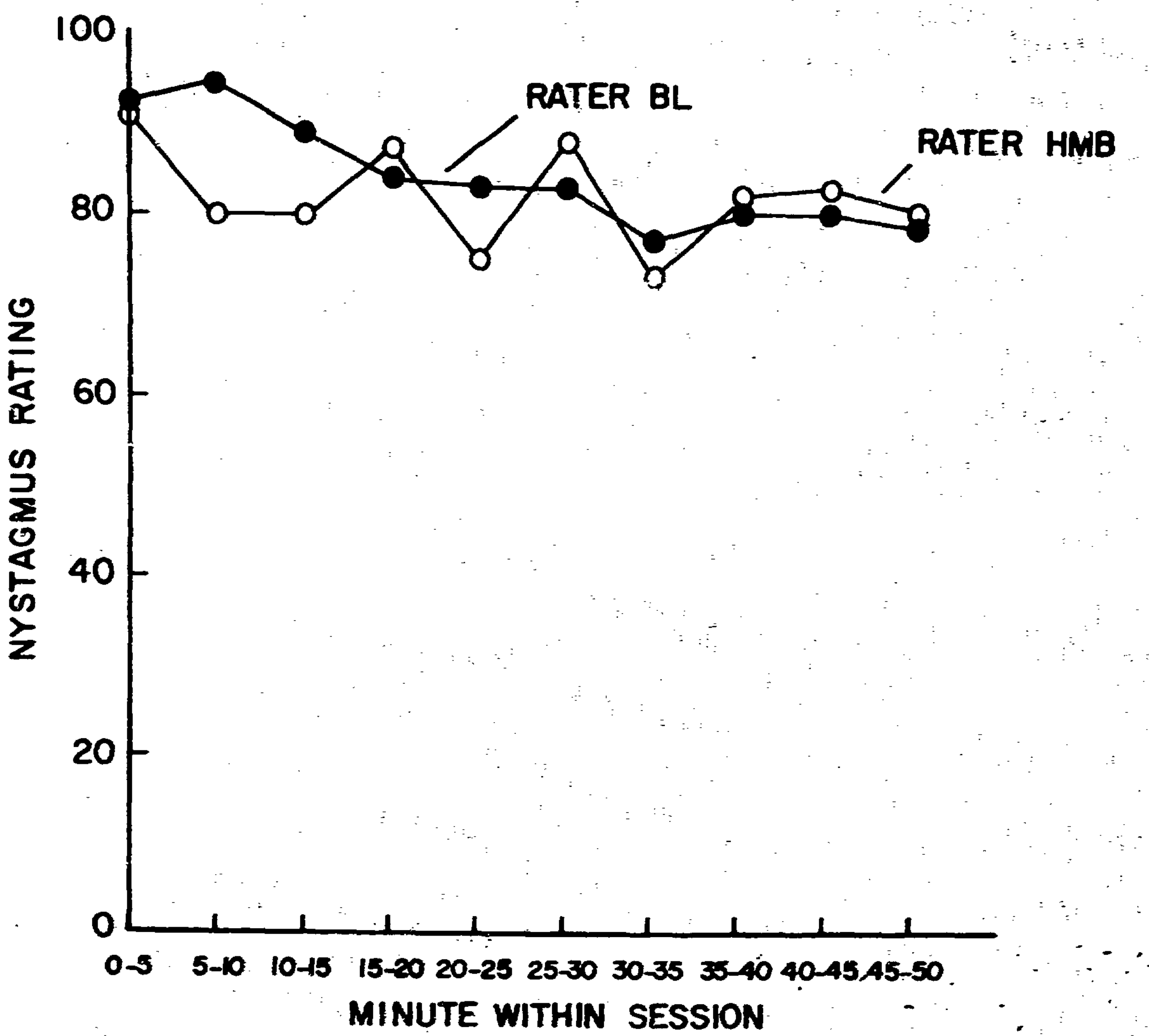


FIGURE 33. A GRAPHIC REPRESENTATION OF A CASE WHERE LOW RELIABILITY (R = .423) BETWEEN RATERS WAS OBTAINED

record on which a low reliability between raters (r = .423, Table 3 and Figure 33) was obtained was also tested for internal reliability within a rater after the low reliability between raters was found above. The correlations were r = .801 for BL and r = .729 for HMB.

Discussion and Conclusions

A method of scoring vestibular nystagmus eye movement responses during protracted sinusoidal oscillation was described. The work of Wendt (1936, 1965) suggested that aspects of these types of eye movements bear a relationship to the mental state of the subject. Eye movement records in this study were first scored by Wendt (GRW), and these scores were used to provide consensual validity. Correlations between the author (RK) and GRW were high. To determine the feasibility of communicating these criteria to others not acquainted with vestibular functions *per se*, seven college graduates (physical science majors and student pilots) were trained in the use of these criteria. The scorings assigned by one of these men (GA), trained by the author (RK) compared well with GRW and with RK. In addition, reliability, as well as face validity, were shown for the method when two subjects were scored by RK and GA under different conditions of control of mental state.

The relationships of scores assigned by the two men trained by RK (i.e., GA and BL) were high when compared to those of RK. The scores of five men, three of whom worked as a team (DU, GI, HMB), were concordant with those of BL and with those of RK; no important advantage appeared to accrue those trained by RK or those trained by BL. Insofar as the assessments of RK agree with those of GRW, it is felt that this method has been demonstrated to have validity as well as substantial reliability. Although reliabilities were generally high ($r > .90$) there was one exception: This was obtained in a subject whose nystagmus response did not change greatly over the period of oscillation.

It is felt that if assessments of eye movement records like these are attempted in the future, it would be useful to review the entire record prior to scoring so that particular caution could be taken with records with low variability. The fact remains, however, that high reliabilities will be difficult to obtain when variability is low, although the problem may be more statistical than real. Furthermore, while the effort to sample portions of a record, rather than score it in entirety were largely successful, it would appear that records which show low variability over time also attenuate the reliability of abbreviated scoring procedures.

References

Brown, J. H. Acquisition and retention of nystagmus habituation in cats with distributed acceleration experience. Journal of Comparative and Physiological Psychology, 1965, 60, 340-343.

Brown, J. H., & Crampton, G. H. Concomitant visual stimulation does not alter habituation of nystagmic, oculogyral or psychophysical responses to angular acceleration. Acta Oto-Laryngologica, 1965, 61, 80-91.

Collins, W. E. Task-control of arousal and the effects of repeated unidirectional angular acceleration on human vestibular responses. Acta Oto-Laryngologica, 1964, 34, Suppl. 190.

Guedry, F. E., Jr., & Graybiel, A. The appearance of compensatory nystagmus in human subjects as a conditioned response during adaptation to a continuously rotating environment. Pensacola, Fla., USN School of Aviation Medicine/NASA Report No. 61, 1961.

Melvill Jones, G. Discussion of vestibular stabilization of eye movements. In P. Bach y Rita & C. Collins (Eds.) Symposium on the control of eye movements. New York: Academic Press, 1971, in press.

Niven, J. I., Hixson, W. C., & Correia, M. J. An experimental approach to the dynamics of the vestibular mechanisms. In The role of the vestibular organs in the exploration of space. Pensacola, Fla., NASA Special Report No. 77, 1965, 43-54.

Robinson, D. A. The oculomotor control system: A review. Proceedings of the IEEE, 1968, 56, 1032-1049.

Wendt, G. R. The form of the vestibular eye movement response in man. Psychological Monographs, 1936, 45, 311-328.

Wendt, G. R. Some characteristics of vestibular eye movements. In Accelerative Forces. A symposium: Psychophysiological factors in spatial orientation. Washington, D. C., Office of Naval Research, Department of the Navy, NAVEXOS P-966, 1950, 36-42.

Wendt, G. R. Man and motion. In Field & Magoun (Eds.) Handbook of physiology, Section IV. American Physiology Society, 1964, 999-1005.

Wendt, G. R. The nature of adaptation to oscillatory rotation. In The role of the vestibular organs in the exploration of space. Pensacola, Fla., NASA Special Report No. 77, 1965, 133-139.

Wolfe, J. W. Evidence for cerebellar control over habituation of vestibular nystagmus. Unpublished doctoral dissertation, University of Rochester, 1966.

Young, L. R. A control model of the vestibular system. In International Federation of Automatic Control. A symposium on technical and biological problems in cybernetics. Yerivan, Armenia. Russia, 1968, 1-14.